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ABSTRACT

This twenty-fourth annual report of the National Science Foundation (NSF) describes the research project support activities, national and international programs, research applications, and science education studies for the fiscal year 1974. It also includes appendices and a statement by H. Guyford Stever, the director of NSF. Scientific research project support supports and strengthens fundamental research in all fields of science. Approximately 13,000 proposals were acted on in 1974. One of the activities under the direction of the National and International Programs Directorate was the establishment of an Office for Climate Dynamics. In 1974 the Research Applications Directorate completed the third year of operations of its RANN--Research Applied to National Needs--program. During this time RANN was pointed sharply toward national problems in energy, environment and productivity. The report lists the major objectives of the Foundation's fiscal year 1974 science education improvement activities. (LS)

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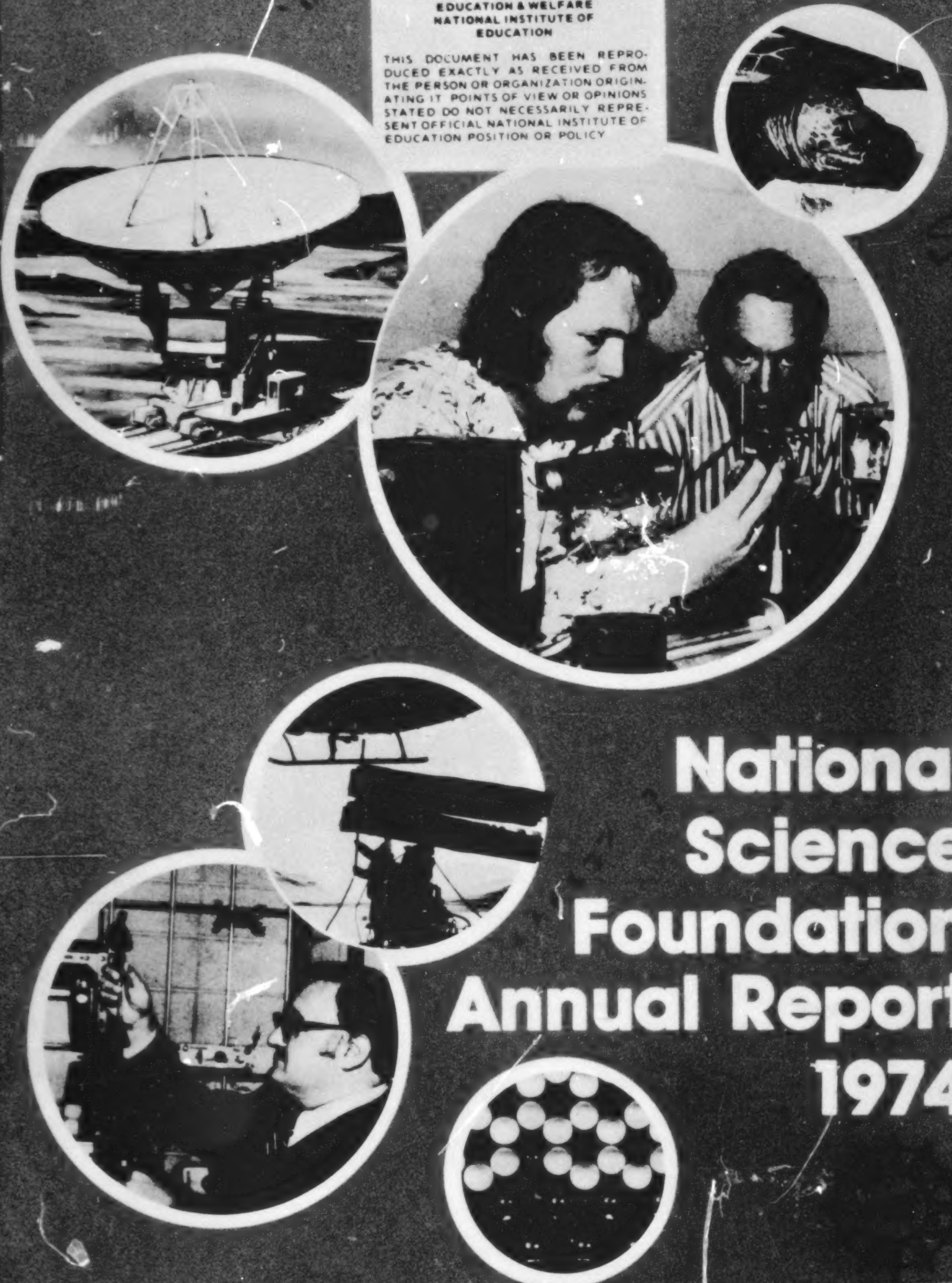

National Science Foundation Annual Report 1974

National Science Foundation

Twenty-Fourth Annual Report for Fiscal Year 1974

2a.

Letter of Transmittal

Washington, D.C.

Dear Mr. President:

I have the honor to transmit herewith the Annual Report for Fiscal Year 1974 of the National Science Foundation for submission to the Congress as required by the National Science Foundation Act of 1950.

Respectfully,

H. Guyford Stever
Director, National Science Foundation.

The Honorable
The President of the United States.

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Director's Statement

As our Nation approaches its third century and as Western Society approaches its third millenium, we enter an era that may be recognized as a turning point in human history. It is not difficult to realize why we have arrived at this point. The predominant reason is that through the marriage of science and technology we have created an industrially based society that up to now has been able to sustain and advance a rapidly growing world population.

The shift from an economy based on agricultural subsistence to one based on modern industry has been responsible for explosive growth, not only in population size but in a spectacular rise in mankind's activities—in mobility, speed of communication, range of knowledge, production of goods and services, and in the number of interfaces within his natural and social systems. Although much of this process is based on human innovation and industriousness, it is based also on humanity's exploitation of the natural world. It draws heavily on nature's capital, particularly on the store of nonrenewable resources, and it impacts heavily on her environment and living resources.

While many have long warned that such growth could not continue indefinitely, their admonitions have usually been taken with a theoretical grain of salt. A combination of human ingenuity and nature's bounty has always seemed to disprove the Malthusians, or at least move the day of reckoning into the distant future. In the past whenever scarcities conjured up the ghost of Malthus to predict impending doom, the ghost of Micawber seemed to appear beside him telling us that "Something will turn up." And fortunately, up to now it has. As we depleted one resource we were able to find a replacement. As we overtaxed one region of the Earth environmentally, we found the means to move on. And as we reached the limits of one technological achievement, we were able to find another to exceed its performance.

But in recent years we have been forced to view the increasing problems of growth with a new degree of sophistication. That sophistication, also a product of science and technology, has urged us to make a more realistic appraisal of the human condition in relation to the physical world that supports it. Initially this appraisal has generated much speculation concerning the future of human growth, raising a host of questions not only over the possibility of feeding projected populations but over the environmental, economic, and social consequences of the continued industrial development of the world along present lines.

If this speculation, given impetus by some new scarcities now appearing, has led to and intensified the debate over matters of growth, it has also brought forth more penetrating thought over the future role of science and technology. While there are some who fear that further advances in science and technology will only fire the engine of indiscriminate growth, there are others who feel there is a necessity for better and more wisely applied science and technology to enable better control and direction of growth and to allow us to continue to expand our physical frontiers.

This latter group also shares the belief that we can expand our physical frontiers only by expanding our knowledge frontiers, and that knowledge is a form of capital capable of allowing us to replace, in effect, the capital we have withdrawn from the Earth's supply of finite resources. Perhaps a good example of this effect lies in our potential ability to develop the means to use solar energy, directly and in all its manifestations, as a form of energy income to replace the energy capital depleted through our use of the nonrenewable fossil and fission fuels.

Increased knowledge capital, particularly that gained from a sound program of basic research, can have other very beneficial effects. Environmentally speaking, it can help us to understand better the physical and social limits within which we must operate in order to keep our natural and manmade systems individually viable and symbiotically compatible. In terms of economics, it can help to increase the efficiency with which we use limited resources, thus moderating their cost as we draw down on them and giving us the time to search out and develop alternatives. And related to social change, increased knowledge can help us to use both our physical and human resources more effectively, improving our institutions and their distribution of goods and services, perhaps moving us toward a life characterized by more quality for less quantity. This may be the major thrust of science and technology in the years ahead, even though we can still expect considerable quantitative growth as much of the world seeks further development.

Another important thrust in science and technology—one characterized for some time now by the growth of interdisciplinary research in the physical, social, and managerial sciences—is the interest in systems. Humanity's pervasive influence and impact on both nature and our own global society has led us to a stronger recognition that we operate within systems wherein we must take note of and deal with a myriad of interrelated factors. Never has this been brought home more forcefully than during the past year when, following the Mid-East War and its resulting oil embargo, disturbances within the relationships between energy, economics, environment, food, materials, and international politics seemed to ricochet around the world.

All this is bound to have an effect on the state of science and technology, emphasizing that we must intensify our search for new knowledge, for ways to organize and apply it more effectively for man's benefit. This 1974 Annual Report of the National Science Foundation reviews a program that illustrates in effect how one agency of the Government is moving in that direction and attempting to contribute to the amelioration and solution of some of the problems we face as a Nation.

In line with this major effort, the Foundation continued to emphasize its support of basic research in order to expand the frontiers of knowledge in all scientific areas. The principal instrument of such support is the Foundation's Scientific Research Project Support Program, which funds research in the physical, environmental, biological, engineering, computing, and social sciences. The vitality and growth of all these fields must be maintained if we are to have the scientific and technological wherewithall—the knowledge capital—to deal intelligently with the increasingly complex relationships within our society and with the natural world.

In reviewing the Foundation's programs, one will discover that the varied research projects fall into certain broad areas related to our physical and human resource needs. One such area decidedly is energy. Projects bearing on all aspects of our energy situation can be seen throughout the Foundation's programs, in Scientific Research Project Support, in Research Applications, in Science Education, in National and International Programs, and in policy and planning activities.

We know that fundamental research in all fields of science can make a multitude of contributions related to energy. By way of better organizing and coordinating the Foundation's basic research support toward this end, the Research Directorate established an Office of Energy-Related General Research. An initial effort of this office was the identification of 45 areas of energy-related research which might receive priority support from the Foundation. A series of workshops that included experts from the universities, industry, and government was organized to examine the challenges and opportunities inherent in these areas. It is interesting to note that these areas run the gamut of research interest, including the physical and biological sciences, the earth and environmental sciences, the social sciences, and engineering. Reviewing these, one sees that solutions to our energy problems can be found through a better understanding of such diverse research subjects as combustion, corrosion, and catalysis; electromagnetism, ecology, and economics; radiation effects, reaction mechanisms, and remote sensing, to name only a few. Increased knowledge of basic phenomena can help us to develop better energy technologies, discover alternative energy sources, and learn to live better with what will be available to us.

Much of that basic knowledge acts as underpinning for the energy programs being supported by the Foundation's RANN program—Research Applied to National Needs. RANN energy research focuses on energy systems, technologies, and resources while also dealing with the environmental and economic aspects of energy. The studies on systems involve both technological and social systems, for both the operations of machines and the attitudes and activities of people have a great bearing on our conservation and effective use of energy. From the standpoint of technologies and resources, the RANN programs continue heavy emphasis on solar and geothermal energy with significant accomplishments toward proving the feasibility of the solar heating and cooling of buildings.

The Nation's energy situation has brought into sharper focus the interface between energy and the environment. Many programs throughout the Foundation are supporting projects that will provide a better basis for resolving the energy-environment conflicts. In initiating its new program on Environmental Effects of Energy, RANN has begun a concerted effort to examine the environmental impact of old and new energy technologies with the intention of finding ways to minimize the economic and social, as well as environmental, problems that may occur as we seek to improve our energy position.

The Foundation's interests in the environment go far beyond its relationships to energy. The work of NSF's directorates involves such far-ranging environmental interests as the biological effects of environmental changes on mankind and throughout the entire ecosystem, and the effects of our industry and technologies on our natural systems—our lakes, rivers, oceans, and atmosphere. Their programs are exploring more broadly how all aspects of the total environment operate. They seek a better understanding of the basis of our climate and weather. Through such an understanding, perhaps we will be able to address the all-important question, "Is our climate changing, and if so, how?" Through large-scale international research projects, such as the Global Atmospheric Research Program (GARP), the Mid-Ocean Dynamics (MODE) field experiment, the Climate: Long-term Investigation, Mapping and Prediction (CLIMAP) program, and other programs on land, in the seas, and in the air, we are pursuing basic information that will help us answer this question and others about climate and weather. Answers to these questions could prove vital to human survival. If large-scale weather and climate changes lie ahead, any advance warnings on them might buy us some time to cope with them, to act in anticipation of their possible effects on world food production and other essential areas.

We are, of course, confronted daily with immediate as well as long-range environmental challenges. The Foundation's programs have become increasingly involved in the study of some of nature's constant threats to man--in the form of earthquakes, floods, hurricanes, hailstorms, and other extreme meteorological events. Our interest is not only in a better understanding of the causes and nature of these hazards but in developing measures to protect ourselves from them. Studies we support show that much can be done to mitigate disasters to save human lives and reduce the economic impact of these hazards. Progress along these lines has been made particularly in understanding earthquakes and their effects and engineering for earthquake-resistant structures. NSF-supported scientists have also learned a great deal about hailstorms and have had some success in determining the feasibility of suppressing their disastrous damage to crops. Tornados are another devastating meteorological phenomenon under study.

In addition to energy and environment the Foundation's programs are concerned with another broad area related to our immediate and future well-being—that is, the matter of resources. As President Ford has stated, "One of the essential lessons of the recent energy crisis is that if we are to prevent shortages of natural resources in the future, we must plan for the future today. Our resources, however abundant, are not inexhaustible. They must be conserved and replenished." In our NSF programs aimed at upgrading our understanding and use of natural resources, as in our energy programs, there is no one repository of research support. Rather, our relationships to resources, both renewable and nonrenewable, are reflected throughout many and diverse programs. Examples of this are striking. Take, for instance, the matter of food—one of our most important renewable resources. Among the programs supported by our Research Directorate is a large one being conducted in cooperation with the Environmental Protection Agency and the U.S. Department of Agriculture investigating the possibilities of the biological regulation of pests—pests which take a huge annual toll of our food and forest crops. Success in this field might not only reduce the large losses of food and forest products incurred annually but might do so without the need for chemical pesticides with their sometimes undesirable environmental and health effects. Another biological research program related to food, the program on nitrogen fixation, is concerned with both the possibility of improving food production and allowing us to cut down on the huge demand for synthetic fertilizer. If scientists were able to develop more plants that are capable of biologically fixing their nitrogen needs in the soil, we could eliminate some of the large energy demand involved in chemical fertilizer production and at the same time reduce some of the environmental and health problems associated with excessive runoff of nitrates into our water systems.

Food-related research is also conducted through our programs investigating the living resources in our oceans and coastal zones. By studying the upwelling phenomena that bring nutrients up from the depths of the sea and sustain its food chain, and by investigating the impact of human activities on sea and shore life, NSF-supported scientists are learning much that can help us improve our management of these valuable resources.

Studies supported by the Foundation's programs are involved with many renewable resources other than those which can serve as food. Among these are sources of energy and building materials. Interest is growing in the bioconversion of animal and plant materials into solid, liquid, and gaseous fuels. As a result, we are funding research into the potential of a marine energy farm that can grow many square miles of kelp to be converted to burnable methane gas, the use of land farms capable of growing plants for fuel, as well as for food and industrial chemical byproducts, and the economics of using agricultural waste as a major source of energy.

One of our most useful renewable resources has always been wood, which has served man for centuries as a source of fuel, paper, and building materials. In spite of all our experience with this great resource, there is the belief that we have vastly underrated its value and potential. We are therefore pursuing a program of wood engineering that is revealing many new and better ways we can use wood, ways that will improve both the engineering and economic aspects of its use.

Concern over current and projected material shortages is also focusing our attention more strongly on research involving nonrenewable resources. Here again the Foundation's programs run a gamut of interests and are showing a variety of results. The Seabed Assessment program has sponsored research that is indicating potential sites for new oil production as well as revealing potential sources of heavy metals in sediments on the ocean floor. Programs in physics, chemistry, engineering, and the earth and materials sciences are telling us more about the properties of, and prospects for using a greater number of the substances that comprise the planet's crust, waters, and atmosphere. We have to understand these better and become more versatile in our use of them as our demands grow, both in terms of dealing with relatively shrinking supplies, and meeting the challenges of more demanding technologies. We must understand also the consequences of using such resources and technologies. The relationship between them can be seen most obviously in the demands such energy systems as coal gasification plants, nuclear power stations, and solar energy systems make on our materials needs, calling for improved resistance to corrosion, stress and heat, increased conductivity and reflectivity, and other, more exotic properties.

An important aspect of achieving a greater use and control over the world's physical resources is gaining a better understanding of our human resources. For this reason, an important part of the Foundation's work is concerned with education, the social sciences, economics, productivity, and programs of international scientific cooperation and technology transfer.

Our Science Education Improvement Programs are centered around three major thrusts: the improvement of science education for those who seek careers in science; its improvement for scientific literacy—for those who will need a better understanding of science even though they are not entering scientific careers; and the improvement of the efficiency and effectiveness of the educational process itself. These efforts should help to supply the well-trained scientific and technical manpower the Nation needs, while at the same time giving us leaders, managers, and citizens better able to conduct the affairs of a society increasingly dependent on wisely used science and technology.

Upgrading the Nation's science and engineering education to achieve these ends is a long process in which new goals are met by developing new materials and methods for instruction, training teachers and administrators in their use, and implementing the improvements within the educational system. We are making progress in this direction, and are also initiating programs to help deal with associated problems such as the disproportionately low number of women and members of ethnic minorities in the Nation's scientific and technological community.

To make better use of our human resources we need a better understanding of the human being, his social behavior and institutions. We are trying to achieve this through support of the social sciences. Characteristically, our knowledge of why we act the way we do, both as individuals and in our institutions, and what we can do to improve ourselves, has always lagged our understanding and control of physical forces. It also lags our political action. As Marc J. Roberts of Harvard recently pointed out, "Because social science is a camp-follower to public controversy, social and economic policy is often made at a time when only the slimmest scientific results are available." One can see this particularly today in the Nation's and the world's difficulty in trying to understand and deal with rapidly changing economic conditions. Much of the emphasis of the Foundation's programs in the social sciences is directed toward strengthening their scientific base. Historians of science tell us that the skepticism sometimes directed today against the social sciences resembles closely the criticism directed against chemistry and physics in the early days of their development as sciences. By our efforts to develop sound methods and reliable data through social science we may someday have a better handle, so to speak, on our social systems and prevent some of the human hardships and dislocations that take place with unpredicted, uncontrolled, and often traumatic economic and social change.

In addition to developing a better understanding of our human resources and how they operate, we are interested in improving their operations. One important aspect of "applied human resources" is productivity, that relationship between the output of goods and services and the input of labor, capital, land, energy, and other resources that produced them. Today productivity has taken on added importance because of such factors as increased competition in international trade and the soaring cost of energy and materials. Therefore, we are highly concerned with the efficiency and effectiveness of producing goods and services, with the ability to do more with less—less material, energy, and environmental impact. If we can substantially improve our productivity we can reduce the drain on resources and improve the quality of life. In this report you will see the Foundation's increasing interest in productivity in both the private and public sectors. Private sector productivity programs are focusing on such areas as enzyme technology, extractive metallurgy, instrumentation, and automation. Research in these areas could allow us to reap vast new benefits from nature at less cost and with less impact.

Public sector productivity research is helping to spread the fruits of scientific and technological knowledge throughout the Nation, particularly as related to improving services in State and local governments. It operates as a form of science and technology revenue sharing, transferring many benefits developed at the Federal level to States and municipalities and helping the States and cities nurture and use available resources in the universities and industry. There is a growing recognition that we need this type of cooperative effort, that in fact we must become a more totally cooperative society to live with and manage the complexities of today's and tomorrow's life.

Such complexities and the degree of cooperation they call for extend globally and demand an increasing amount of international cooperation. As a result the Foundation now finds itself involved in a number of growing international programs. These programs fall into two broad categories, though administratively they come under many arrangements. There are those programs in which our scientists and those of other nations work side by side, share facilities, and seek common objectives. These are characterized by such "big science" projects as the Global Atmospheric Research Program (GARP), whose first major effort GATE—the GARP Atlantic Tropical Experiment—took place last summer, and the latest work of the *Glomar Challenger* in the Deep Sea Drilling Project. There are also those cooperative scientific activities in which scientists of many nations exchange visits, work in each other's laboratories, and share scientific information. An extension of this latter activity, which had its roots far back in the history of science, is the transfer of technology. The Foundation is now involved in a growing number of bilateral agreements and agreements for cooperation through which we are not only sharing information but exchanging technology that could have a profound bearing on the economic and social development of other areas of the world.

As the Foundation's role and responsibilities grew in fiscal year 1974 so did those of its Director. This year saw the Director of the Foundation assume the additional role of Science Adviser to the President. This resulted from the Presidential announcement, through the Reorganization Plan No. 1 of 1973, that he was reducing the size of his Executive Office and returning more responsibilities to operating agencies. In the Reorganization Plan, the Office of Science and Technology was abolished and its functions were assigned to the Director of NSF. To assist the Director in carrying out his broadened responsibilities, he established two advisory groups, a Science and Technology Policy Office (STPO) and an Office of Energy Research and Development Policy (OEP). Both offices, after building highly qualified staffs, have been providing valuable input to the Science Adviser in his effort to strengthen Federal science programs.

The STPO has focused its analytical capability on the assessment of emerging science and technology issues, reviewed R&D budgets of the R&D-performing Federal agencies, and developed science and technology policy options. Some of the major areas of interest which the STPO staff is addressing include: a world food and population study, materials, social research and development, industrial research and development, international science and technology issues, environmental and health research, facilities for high energy physics research, space program activities, and technology transfer. STPO conducts a program of outside grant and contract support in addition to drawing upon in-house NSF staff expertise.

The OEP has been providing technical support to Executive Office of the President entities such as the Office of Management and Budget and the Federal Energy Administration. In addition, it provides coordination of R&D policy among all energy R&D-performing agencies.

Some specific activities of the OEP include:

☐ Technical and staff support to the Director as Chairman of the R&D Committee of the Federal Power Commission National Power Survey.

☐ Assistance in developing guidelines for transmission to the Chairman of the Atomic Energy Commission for use in developing a 5-year, $10-billion energy R&D agenda.

☐ Assistance to the Office of Management and Budget in analyzing agency submissions in the energy R&D area for the fiscal year 1975 budget.

☐ Development of a Critical Path Analysis of Project Independence.

☐ Support to the Director as Chairman of the White House R&D Advisory Council.

In addition to his role as Science Adviser, the Director was designated to serve as Chairman of the Federal Council on Science and Technology (FCST). One of the initial activities of the FCST was a review of the committee structure to improve its relevance and effectiveness. New committees have been established on materials, the International Geodynamics Program, and domestic technology transfer. Committees which have completed their objectives and have been terminated are the Committee on International Technology Transfer and the Committee on Ecological Research.

Throughout the pages of this annual report there is evidence that our relationship with the world of nature and the world of man is rapidly changing, and that the shrinking of space, the collapse of time, and the growing use and abuse of our physical world—all accredited in large measure to the growth and use of science and technology—are inevitably making greater demands on science and technology. More than that they are making demands on the men and women who have inherited this legacy of human knowledge which has become a dominating force of civilization. They are challenging the scientist and the citizen both to adapt to change and master change, to understand growth and control growth, and to do this within the framework of a better knowledge of what we are and what we might become. Ultimately, science and technology are but means to these ends, and it is to these ends tnat the National Science Foundation continues to dedicate all its efforts as it helps to support and guide the Nation's scientific enterprise.

Research Project Support Activities

A major responsibility of the National Science Foundation is to support and strengthen fundamental research in all fields of science. Scientific Research Project Support, managed by the Research Directorate through more than 80 program offices, is the Foundation's principal program for this purpose. Approximately 13,000 proposals were acted on in fiscal year 1974, representing essentially all fields of the environmental, physical, life, computer, engineering, and social sciences, as well as mathematics. Of this number 6,400, or 49 percent, resulted in awards totaling $281 million, as compared with 44 percent in fiscal year 1973. The distribution, number, and amount of grants according to field of science for fiscal years 1972, 1973, and 1974 are shown in Table 1. Grants were awarded to 456 institutions, including 321 colleges and universities, in all 50 States, the District of Columbia, and Puerto Rico; 93 percent of the funds went to academic institutions. Table 2 shows the average distribution in fiscal year 1974 for approved cost items on the research grants.

Essentially all proposals to the Research Directorate are unsolicited, and most are submitted by academic institutions in the United States. Support at those institutions affords graduate students an opportunity for research experience under the direction of research scientists as a byproduct of the quest for new scientific knowledge. Proposals are reviewed and evaluated by active researchers in the field represented, as well as by Foundation staff. On the average, 3 to 5 reviewers are asked to comment on a particular proposal; in the course of a year between 18,000 and 20,000 different reviewers, serving without compensation, are called upon to assist in this process, which culminates in a recommendation for action by a Foundation program officer. In some disciplines, proposals may also be reviewed by assembled panels, and certain proposals are reviewed by the National Science Board.

In selecting proposals for support, the Foundation seeks those of highest merit, evaluating such factors as the relationship of the proposed work to the state of knowledge in the field, the probability that the research will contribute significantly to the field, the soundness of the research plan, and the qualifications of the investigator to successfully carry it out. The final recommendation for support depends upon the availability of funds allocated to that particular field. In making its distribution by fields within the project support program, the Foundation considers the dynamics and trends in support by other funding sources of each field, the relative readiness of the different areas of research to move ahead, and national priorities for scientific resources.

In response to the world crisis in energy resources, a major Federal effort was launched in 1974 to enhance energy resource availability. An important component of this effort is research to broaden our base of scientific understanding of many aspects of the problem. A significant part of the research responsibility has been assigned to the National Science Foundation, with the Research Directorate focusing particularly on those problems in basic research that relate in some important way to problems of energy. Much of the ongoing research supported in 1974 and prior years is related to energy research needs, and this effort will be expanded. To provide management emphasis to this urgent national program, an Office of Energy-Related General Research has been established in the Research Directorate to plan and coordinate the work supported through the Scientific Research Project Support program. Forty-four areas of energy-related research have been tentatively identified as having a close relationship to presently perceived solutions to the energy problem. To sharpen understanding of the research opportunities in energy-related basic research, the Foundation is sponsoring a series of workshops to bring together experts from colleges and universities, industry, and government to identify key problems. The workshops are outlining energy research opportunities that will contribute to orderly but imaginative development of priority research programs.

Foundation involvement in the U.S.-U.S.S.R. Cooperative Agreement on Science and Technology was substantially increased in 1974 with the obligation of $3.4 million from the Scientific Research Project Support program to support U.S. scientists engaged in cooperative scientific activities jointly approved by the two countries. Principal emphasis in 1974 was on microbial synthesis, computer applications to management, chemical catalysis, and science policy studies. A number of working group meetings have been held in both countries, resulting in agreements for further expansion of cooperative activity.

The following chapter discusses some highlights of recent research supported by the Research Directorate. Also included are scientific highlights of activities of the National Research Centers. Activities under the two national programs administered by the Research Directorate—the International Biological Program and the Global Atmospheric Research Program—are covered in a later chapter with other national programs.

Table 1

Scientific Research Project Support
Fiscal Years 1972, 1973, and 1974

[Dollars in millions]

	Fiscal year 1972		Fiscal year 1973		Fiscal year 1974	
	Number	Amount	Number	Amount	Number	Amount
Astronomy	135	$ 8.01	170	$ 8.80	161	$ 9.30
Atmospheric Sciences	218	11.71	232	11.93	242	12.24
Biological Sciences	1,644	54.00	1,584	56.22	1,641	58.93
Chemistry	633	24.52	675	25.08	730	26.65
Earth Sciences	257	9.48	296	9.76	284	11.01
Engineering	665	25.43	663	26.16	711	28.09
Physics	271	33.28	298	34.88	315	36.73
Social Sciences	619	22.45	635	23.63	617	24.92
Materials Research	392	33.39	409	34.97	469	35.56
Oceanography	273	12.55	287	12.66	299	13.34
Mathematical Sciences	693	13.75	758	14.06	766	14.50
Computer Research	155	12.54	131	9.90	165	9.76
TOTAL	5,955	$261.11	6,138	$268.05	6,400	$281.03

Table 2

Scientific Research Projects, Average Distribution of Funds by Type of Expenditures for Fiscal Years 1972, 1973, and 1974

	Fiscal year 1972		Fiscal year 1973		Fiscal year 1974	
	Amount	Percent of total	Amount	Percent of total	Amount	Percent of total
Professional Personnel						
Faculty	$6,458	14.7	$6,332	14.5	$6,543	14.9
Research Associates	3,295	7.5	3,232	7.4	3,337	7.6
Research Assistants	5,096	11.6	5,022	11.5	4,830	11.0
Other Professional	1,977	4.5	1,878	4.3	1,844	4.2
Total—Professional Personnel	16,826	38.3	16,464	37.7	16,554	37.7
Other Personnel	3,471	7.9	3,275	7.5	3,161	7.2
Fringe Benefits	1,801	4.1	1,922	4.4	2,064	4.7
Total—Salaries and Wages	22,098	50.3	21,661	49.6	21,779	49.6
Permanent Equipment	2,460	5.6	2,402	5.5	2,371	5.4
Expendable Equipment and Supplies	3,119	7.1	3,144	7.2	2,986	6.8
Travel	1,318	3.0	1,310	3.0	1,361	3.1
Publication and Printing	659	1.5	655	1.5	615	1.4
Computing Costs	1,142	2.6	1,092	2.5	1,098	2.5
Other Costs	2,592	5.9	2,926	6.7	2,898	6.6
Total Direct Costs	33,388	76.0	33,190	76.0	33,108	75.4
Indirect Costs	10,544	24.0	10,481	24.0	10,802	24.6
Total Average Grant	$43,932	100.0	$43,671	100.0	$43,910	100.0

MATHEMATICAL AND PHYSICAL SCIENCES

During the past year public concern has increasingly focused the Federal Government's attention on research and development efforts related to the Nation's energy problem. The Mathematical and Physical Sciences Division has participated in activities supporting such efforts. NSF grantees, non-NSF-supported scientists, NSF staff, industry spokesmen, and other Federal officials have, within recent months, conducted workshops on energy-related topics and prepared reports, suitable for publication, defining the dimensions of the problem areas. Some of the research areas in which workshops have been held or are planned are: electrochemistry, catalysis, atomic and molecular physics, chemistry of coal, and colloid science and oil recovery. These workshops are part of a continuing effort to inform the scientific community of the scientific needs of industry and government and to inform industry and government decisionmakers of the options that research might make available.

In addition to the direct contributions of some of our grantees to solution of energy problems, a large fraction of the division's existing research projects, which are supported for their basic research interest, also have energy implications. Of course, the bulk of the program continues to be dedicated to high-priority basic research and not directly related to energy, as typified by research results reported on the following pages. However, this report could just as easily have cited examples that are energy related. For instance, research in physics could have been represented by a description of a calculation of the dynamics of pellet compression, which allows optimization of energy production in laser fusion. In chemistry, any one of a number of electrochemistry projects relevant to the kinetics mechanism, thermodynamics, and transport properties of ions and electrons through liquid, solid, and gaseous media might have been mentioned. (Our electrochemistry workshop has determined that the principal impediment limiting the rate of progress in the development of energy transduction, conservation, and storage devices is a lack of fundamental knowledge in these areas.)

Therefore, our focusing on those areas of basic research possessing strong energy implications will not appreciably distort the character of the research we already support. In point of fact, no attempt, beyond the obvious step of requiring that energy-relatedness be feasible within the foreseeable future, has been made to narrow the list of research areas that would be eligible for any energy-related research funds that might be specially provided in future years. Consequently, the list of energy-related research areas spans a wide spectrum (catalysis, thermodynamics, physical and chemical separation, radiation effects, optimization, systems theory, plasma dynamics, instrumentation, etc.) with a wide range of potential application (pollution monitors, energy storage, fusion devices, improved industrial processes, more efficient energy utilization, etc.).

PHYSICS

Doppler-Free Spectroscopy

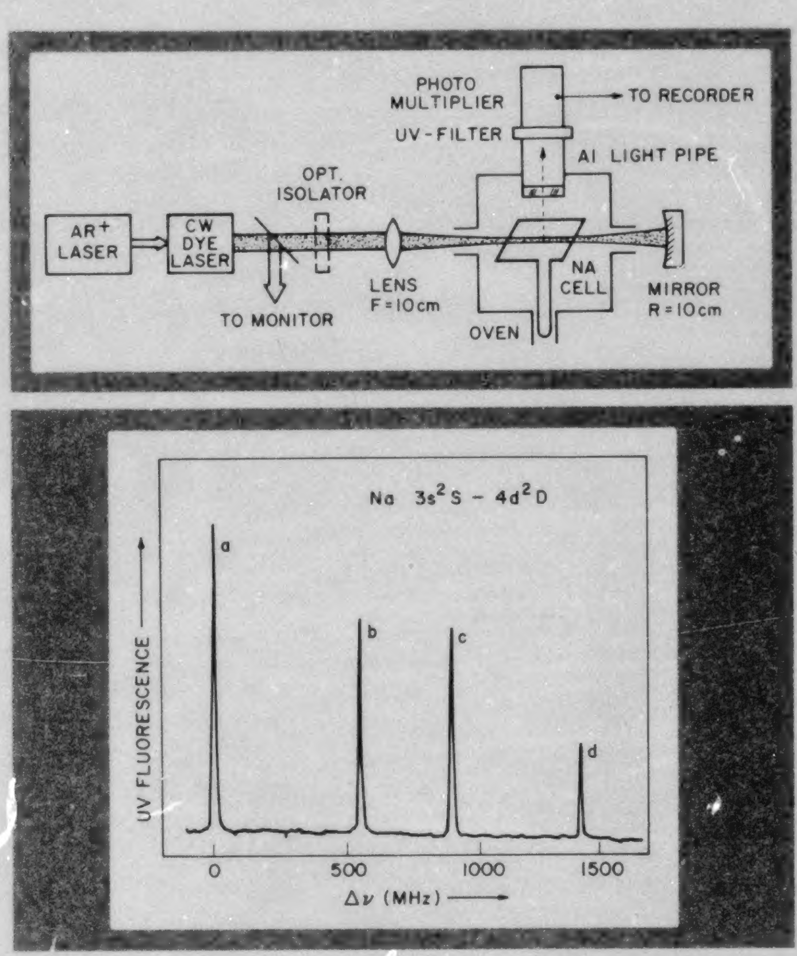
In one of those events so typical of research, four groups have independently and almost simultaneously demonstrated two-photon absorption in sodium vapor without blurring from Doppler broadening. The technique appears to open up a new way of achieving high-resolution spectroscopy with tunable lasers. It also can be used, for example, to induce photochemical reactions selectively, to separate isotopes, or to provide more precise values for the Rydberg constant and Lamb shifts.

The theory of two-photon transitions was first discussed in 1929. But experimental observations in the visible region have only become possible over the past 10 or 12 years as strong laser sources became available. In 1970 a Soviet group pointed out the possibility of using two-photon transitions for high-resolution spectroscopy without Doppler broadening. A recent visit by V. S. Letokhov of the Institute of Spectroscopy in Moscow to Cambridge and to Stanford, in which he discussed this idea, seems to have stimulated groups at Harvard and Stanford to attempt the experiment. Recently *Phys. Rev. Letters* carried articles by several groups—Harvard, MIT, and one in France—which almost simultaneously have succeeded in observing two-photon absorption. Still more recently the Stanford group reported that they had observed the absorption with a low-power cw laser and obtained much narrower lines than the other groups.

The experiments involve directing a beam from a tunable laser through the gas under study, and then reflecting it back along the same path. The optical transitions to be studied are those which cannot be seen in ordinary spectroscopy: They connect states of the same parity and so can only occur by the simultaneous absorption of two photons, whose frequencies or quantum energies add up to the required amount. Thus, absorption can occur when an atom or molecule absorbs one photon from the original laser beam and another from the reflected beam propagating in the opposite direction. As the laser is tuned, there is a sharp absorption resonance, which is detected by the consequent emission of light of a different wavelength from the excited atoms.

The new method has several unusual properties. The energy absorbed is the sum of the energies of the two photons, so that visible light can produce the effects of ultraviolet. Moreover, the troublesome Doppler broadening from the random thermal motions of the molecules is eliminated. To a moving molecule, the light frequency of one laser beam will appear shifted upward. But the frequency of the light in the oppositely directed beam will be shifted downward by exactly the same amount, and so the sum of the frequencies is not affected by the molecular motion. Consequently, as the laser is tuned, extremely sharp resonances are observed and fine details are revealed. The individual components are observed to have fractional line widths of about two parts in a hundred million, or less than 1 percent of the Doppler-broadened line width.

Morever, the new technique has an important advantage over other methods of avoiding Doppler broadening, such as atomic beams and saturation spectroscopy. The earlier methods select a small fraction of the molecules which happen to be traveling in a particular direction transverse to the light beam. In the two-photon method, all of the atoms can be excited, as the effects of their random velocities are eliminated. Thus, this method seems particularly attractive for selective laser photochemistry, such as isotope separation.



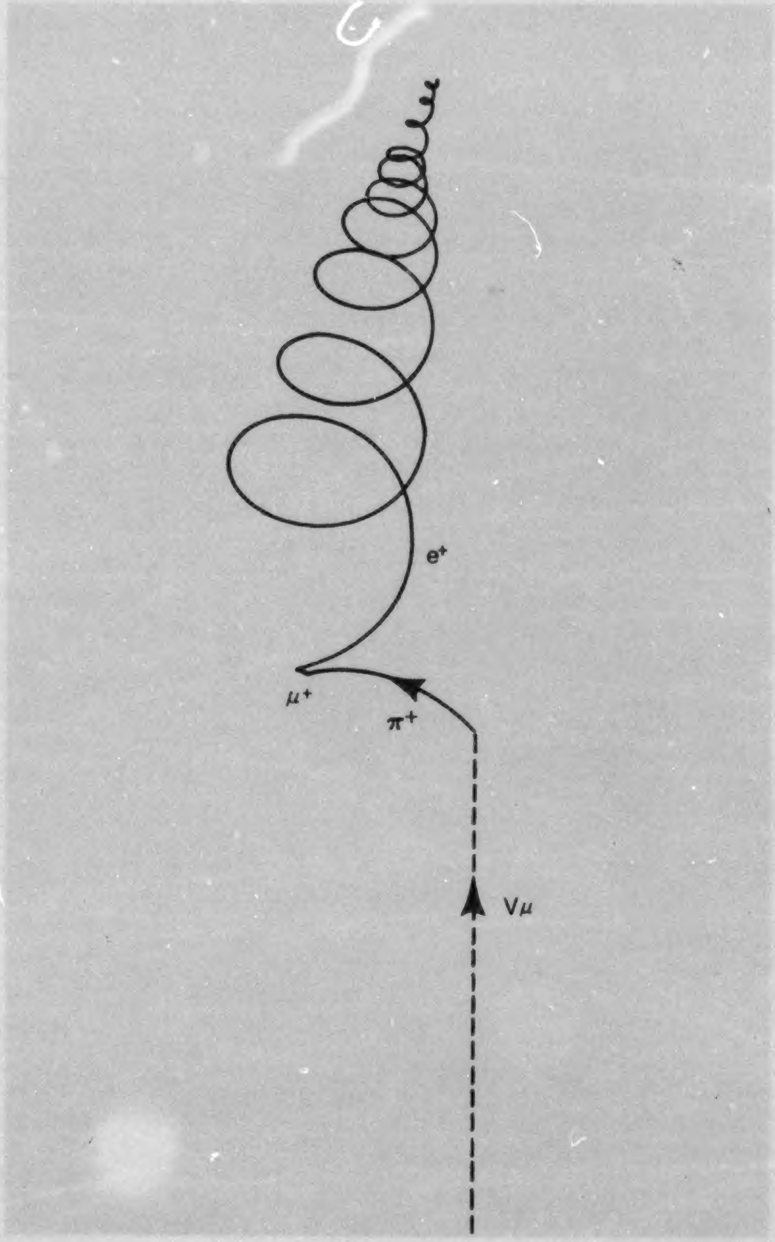
In an experimental arrangement for two-photon spectroscopy of sodium vapor (top), a beam from a tunable laser is directed through a cell of sodium gas to a mirror and then reflected back along the same path. Within the cell, an atom of sodium absorbs one photon from the original laser beam and another from the reflecting beam, thus imparting the sum of the energies of the two photons to the atom. As the laser is tuned, extremely sharp resonances are observed (bottom) and fine details are revealed in the structure of a single line of atomic sodium.

Unification of Elementary Particle Interactions

The interactions of elementary particles appear to be confined to four broad categories. *Gravity* and *electromagnetism* are long-range forces experienced in the everyday world. *Strong interactions*, which hold protons and neutrons together in the atomic nucleus, have a range of about 10^{-13} centimeter. *Weak interactions*, which are manifested only in certain kinds of collisions or decay processes, have a range of less than 10^{-15} centimeter. The apparent disparity is partially alleviated by knowledge that relativity and quantum mechanics lead us to a mathematical formalism, quantum field theory, in which elementary-particle interactions can all be explained by the exchange of elementary particles themselves. The different interaction ranges then become a consequence of the uncertainty principle in quantum mechanics, which can only be satisfied if the range of a force is inversely proportional to the mass of the exchanged particle. Thus, electromagnetism and gravity, which seem to be of infinite range, are due to the exchange of particles of zero mass (the familiar photon and the hypothetical graviton), and the strong interactions are generally believed to arise from the exchange of a large variety of strongly interacting particles (protons, neutrons, mesons, and hyperons of various kinds). Since the weak interactions have a much shorter range than the strong interactions, they must be produced by the exchange of much heavier particles, presumably particles too heavy to have yet been created with existing accelerators.

A quantum field theory tells us how to calculate the rate for any process in terms of a sum of individual processes (involving particle exchanges), each symbolized by a Feynman diagram. In the late 1940's several investigators independently found a limited class of field theories in which the infinities arising in Feynman diagrams with loops occur only as corrections of the fundamental parameters of the theory (such as masses and charges). These infinities could be eliminated if one identified the corrected parameters with the measured values listed in tables of the fundamental constants. But problems remained.

For the strong interactions there is no lack of possible renormalizable theories; rather, the trouble is that the strength of the interaction invalidates any simple approximation scheme, and other calculational schemes have not yet achieved satisfactory agreement with experimental values. Gravitational effects are so weak that one can get no help from experimental measurements, at their current level of precision, in finding the correct theory. However, the weak interactions are strong enough so that there is good experi-



Evidence has recently been found for neutral currents in interactions of elementary particles. Such evidence supports theories of a connection between two of the four forces in nature—electromagnetic forces and weak interactions. This drawing, based on experiments at the Argonne National Laboratory, shows an example of neutral-current process distinguished by the absence of outgoing negative muon or proton tracks. Tracks are left only by charged particles—the positive pion (π^+) which has split from the incoming neutrino (V_μ) and decays into a positive muon (μ^+), which then decays into a positive electron (e^+) visible as a tightly wound spiral. [After *Scientific American*] mental data, and yet weak enough so that approximate calculations are practicable. Therefore, it is not surprising that the most significant recent efforts of theorists seeking a unified field theory have focused on the weak and electromagnetic interactions.

It has been known for many years that the Maxwell field equations of electromagnetism obey a gauge symmetry, based on the group of rotations in two, rather than in three, dimensions. And, for many years it had been speculated that the difference in the apparent strengths of the weak and electromagnetic interactions was due simply to the large mass of the particle exchanged in the weak interactions. Because this exchange involves transfer of one unit of angular momentum, the hypothetical particle exchanged is called the intermediate vector boson. Since at low energies the apparent strength of the weak force is roughly 1,000 times weaker than the electromagnetic force, its participation in nuclear beta decay means that it must carry a positive or negative charge equal in magnitude to the charge of the proton or of the electron. Therefore, a theory unifying the weak and electromagnetic forces would have to find a family relationship between the massless photon, which intermediates the electromagnetic force, and the massive intermediate vector boson.

In 1967 it was suggested that there existed a so-called "broken gauge-symmetry group" that forces the photon and the intermediate vector boson into such a single family. The proposed group contains within it the unbroken gauge-symmetry group of electromagnetism and therefore requires the photon to have zero mass, but the other members of the photon's family are associated with broken symmetries and therefore pick up a large mass from the symmetry-breaking. In the simplest version of this theory both charged (39.8 proton masses) and neutral (79.6 proton masses) intermediate vector bosons are relatives of the photon.

In 1967 there was no experimental evidence for or against this theory. However, it subsequently did pass an internal test that could be made without help from experiment, in that its renormalizability was demonstrated in 1971. Until such time as intermediate vector bosons can be produced directly, the best way to test the theory is to look for effects attributable to the newly predicted neutral intermediate vector boson. The best such test is provided by the fact that only the neutral intermediate vector boson can contribute to processes such as the elastic scattering of neutrinos by protons or neutrons.

Within the past year evidence for neutral-current (neutral intermediate vector boson) processes has at last begun to appear. Experiments at various laboratories (including one by an NSF grantee, Wonyong Lee of Columbia University, using the Brookhaven AGS), have detected a number of events in which muon-type antineutrinos are inelastically scattered by protons or neutrons, without the production of a muon. Such scattering events can apparently only be explained by the exchange of a neutral intermediate vector boson (a neutral current) and are therefore direct evidence for a new kind of weak interaction. Moreover, the inferred collision rates agree well with rates predicted by the new theory.

CHEMISTRY

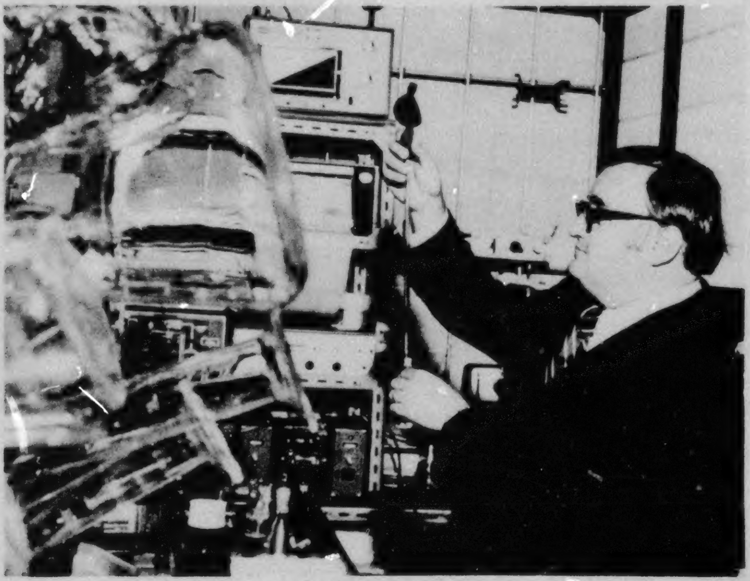
Advances in Chromatography

The importance of the tools of chemical analysis is reflected in the diverse activities using them. Techniques devised for fundamental scientific research soon find their way into everyday use in clinical medicine, food production, public health operations, pollution control, and a host of other routine endeavors contributing to our health and well-being.

One of the major problems that chemists face in developing these analytical tools is that samples to be analyzed are often too complex for direct measurement. Consequently, chemical separation techniques are needed to simplify mixtures so their components can be identified and measured. A very powerful group of separation methods are those using the process of chromatography. With these methods chemical constituents with very small differences in properties (e.g., vapor pressure, solubility) can be separated, measured, and often identified.

Chromatographic separations are based on differences in distribution behavior of substances between two insoluble phases, one of which is usually mobile. The mobile phase may be a gas (gas chromatography) or a liquid (liquid chromatography), while the stationary phase is either a packed bed (adsorbent) or a liquid coated on a porous solid (partition). Separation results from differences in solute migration times through the packed bed, the migration time being related to distribution equilibrium.

Barry Karger at Northeastern University has been studying various aspects of gas and liquid chromatography with the overall goal of improving the methods in terms of speed, convenience, precision, and applicability. He has been examining the determination of optimum separation conditions in temperature-programming gas chromatography. In this programming method, the temperature of the packed bed or column is varied at a controlled rate. Since migration time in gas chromatography is predominately a function of vapor pressure, temperature programming



In studies of gas and liquid chromatography, Barry Karger at Northeastern University works to find optimum methods of separating chemical components to be identified and measured. **(Photo by JET)**

allows one to separate a much wider boiling point range of solutes than simple constant temperature operation. He has developed a method by which optimum temperature programming conditions can be rapidly determined for unknown complex mixtures through the use of a minicomputer. Temperature is only one of a number of chromatographic parameters that need to be optimized, and Dr. Karger is applying the same principles to specify other optimum conditions.

Dr. Karger has also been investigating the use of chemically bonded phases for chromatography. An adsorbent, such as silica, has a surface that is quite heterogeneous and reactive, leading to poor separation and precision. The surface is commonly deactivated by the addition of small amounts of water or modified by the attachment of a different substance. He selected the latter approach for study, and studied the phases formed from reaction of primary alcohols with the silica surface. In examining the chromatographic properties of a series of phases in which the alkyl structure of the primary alcohols was varied while the straight chain length remained constant at eight carbons, he showed the bonded phases to be unique for the separation of relatively small polar molecules. Column efficiencies were remarkably high, revealing these phases to be quite suited to a variety of complex separation problems. Finally, his work revealed the clear importance of adsorption over partition in the equilibrium process. These results are important in the understanding of the relationship of these phases to other stationary phases in gas chromatography.

Liquid chromatography has undergone the greatest development of any separation method over the past 5 years. While gas chromatography works best for volatile compounds, liquid chromatography is well suited to the separation of higher molecular weight substances, ionic species, and thermally unstable compounds. At one time column liquid chromatography was characterized as a slow and inefficient process, but recent work has made this method fast, with performance comparable to gas chromatography. This relates to the fact that column conditions (e.g., temperature, liquid mobile phase) correspond most closely to those needed for pharmaceuticals, biochemicals, and drugs of abuse.

Dr. Karger has also been active in the developments of modern liquid chromatography. Under NSF support he built a computer-controlled liquid chromatographic unit that is useful as a powerful separation unit, as well as a precise analytical instrument. He has indentified many of the factors that determine precision in migration time and quantitation, and by careful control of conditions he is able to reproduce migration time to 0.1 percent relative standard deviation and quantitation to 0.2 percent relative standard deviation. These results are important when one wishes to identify substances (e.g., drugs of abuse) by their migration times or wishes to determine the amount of substances (e.g., analysis of body fluids to determine disease stages) by their fingerprints. In this work Dr. Karger has also produced liquid chromatographic columns with very high efficiencies (70,000 to 90,000 plates per meter) using very small adsorbent particles (about 3 microns in diameter). These are currently used in the separation of complex mixtures.

A striking example of the application of chromatography has resulted from the research of Harry Svec and James Fritz at Iowa State University. Although the potable water supplies of cities and towns are commonly analyzed for hardness, other inorganic constituents, and biological organisms, relatively little is known about the soluble organic compounds that are present naturally or result from some contamination. The pressing need for such information has been widely recognized. This lack of information about the organic content of water exists primarily because, until recently, there was no general analytical method for identifying soluble organic compounds that may be present in concentrations substantially less than 1 part per million (ppm).

In 1972 and 1973 Drs. Svec and Fritz, working mainly under the sponsorship of the NSF (with additional support from the Iowa State Water Resources Research Institute and the City of Ames), developed a method for identifying and measuring the concentration of organic impurities present in drinking water at concentration levels as low as a few parts per trillion (ppt). Their continuing research has resulted in a simple, fast analytical procedure. The required amount of water for an analysis has been reduced from approximately 100 gallons to about 1 gallon, and studies on a large number of model compounds added to water in the 10 to 50 ppb concentration range show that the procedure is quantitatively efficient.

Many water samples have been analyzed using the Iowa State University procedure. Analysis of raw and treated water samples from municipal drinking water supplies of 15 cities in Iowa and Nebraska showed neutral organic impurities ranging from 0.019 to 79 ppb. The most common neutral organic materials found in the drinking water supplies are:

- Plasticizers—common constituents of tubes, hoses, and pipes
- Alkyl benzenes—common in solvents for paints, insecticides, antiseptics, etc.
- Alkyl polyaromatic and heterocyclic compounds—active ingredients of insecticides, wood preservatives, sanitizing mixtures, etc.
- Common industrial solvents—alcohols, ketones, phenols, halogenated hydrocarbons, etc.
- Pre-emergent herbicides—atrazine and related soluble compounds.

More than 150 compounds have already been identified (in about half of these cases, even the specific isomer has been identified), many of which are common in water supplies. In many cases the raw water is less contaminated than the treated water. Presumably the additional contamination results from the treating equipment or even the organic coatings (tar or asphalt) used to prevent corrosion of the iron conduits used to transport the water to consumers.

Extensive analyses of water from ten wells supplying water to the city of Ames, Iowa, were also done, because it was known that some of the wells were contaminated with organic compounds that had entered the aquifer by leaching of residues from a coal gas plant that operated in the city until about 1920. The total impurity concentration was determined for each well, with values ranging from 0.56 ppb to 287 ppb. As a result of these studies, Ames officials have abandoned some wells and revised pumping schedules of other wells, drastically reducing the organic contaminants.

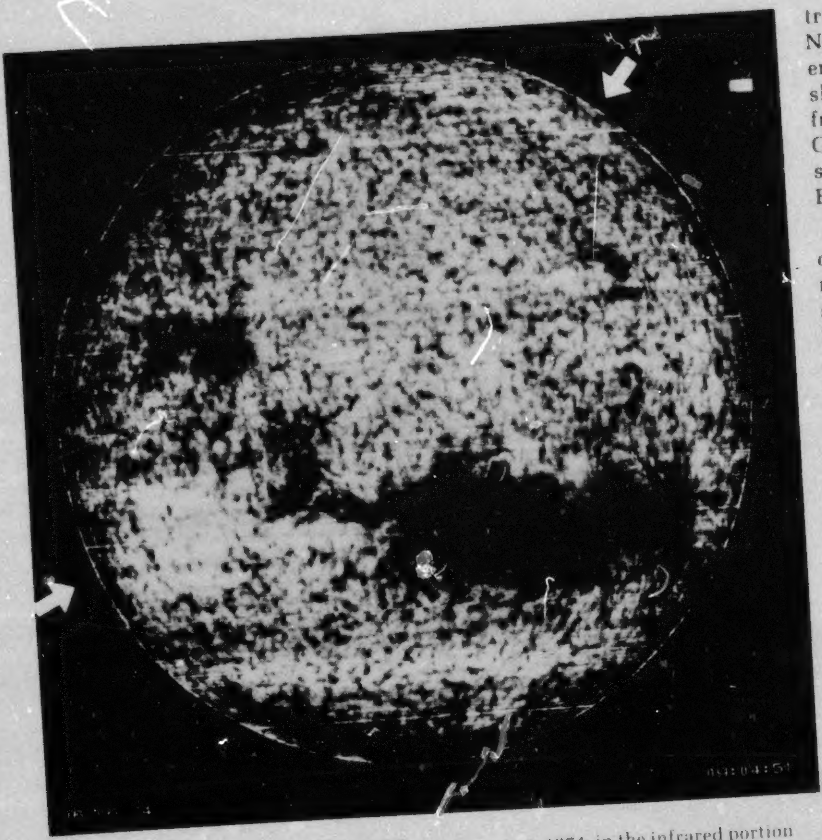
ASTRONOMY

Recent Solar Observations

Neutral helium atoms in the atmosphere in the Sun can be ionized by the extreme ultraviolet and soft X-ray lines emitted by the solar corona, a low-density but very high-temperature region which forms the Sun's outer atmosphere. The singly ionized helium is then able to recombine with free electrons to produce highly excited neutral helium. This, in turn, is capable of absorbing photospheric light at certain specific wavelengths, one of which is at 10,830 angstroms in the near infrared region of the spectrum. If the neutral helium were not first ionized by radiation from the hot corona, this line would be very weak.

Jack W. Harvey of the Kitt Peak National Observatory (KPNO) in Arizona has now shown that the regions of the Sun which do not show the 10,830-angstrom helium absorption line coincide with regions below a so-called "coronal hole." The coronal holes are regions of the corona with anomalously low brightness, first discovered through space observations made with the Orbiting Solar Observatory IV, and further observed by the SKYLAB teams. They are of great interest to solar astronomers since the low coronal brightness is found to occur over sizable areas of the solar surface and to be persistent over periods of many days. Furthermore, the coronal holes also appear to be the source of solar wind enhancements which produce important disturbances in the Earth's immediate space environment. Thus, it is important to be able to continue observation of this newly found solar phenomenon for better physical understanding.

The discovery of the relationship between coronal holes and the presence or absence of helium lines strengthens our understanding of the formation of the helium lines and has allowed observations of the coronal holes to be made from the ground as well as from space. The new Kitt Peak vacuum solar telescope used by Dr. Harvey employs silicon diode detectors which have a high quantum efficiency in the red to near-infrared spectral range (7,000 to 11,000



This spectroheliogram of the Sun was taken June 6, 1974, in the infrared portion
of the spectrum in a very limited wavelength range. In certain dark areas, light
originating from the bright solar surface at this wavelength is absorbed by
helium atoms in the overlying atmosphere which are in condition to absorb light
at this infrared wavelength. In other large areas, where fewer helium atoms are in
condition to absorb light at this wavelength, bright light shines through the at-
mosphere. Such bright areas are seen on the spectroheliogram at 8 o'clock and 1
o'clock (indicated by arrows). These brighter areas coincide with the coronal
holes where the hot corona is nearly absent above that part of the solar surface.
(Photo by Kitt Peak)

angstroms). The output of the spectroheliograph and the magnetograph with which the telescope is equipped takes the form of measures of the intensity, velocity, and magnetic field of the Sun to a resolution of one second of arc. First results indicate that surface magnetic field configurations appear to be basically responsible for the coronal holes, and studies of KPNO magnetograms to elucidate this relation are under way.

The New Naturally Occurring Maser

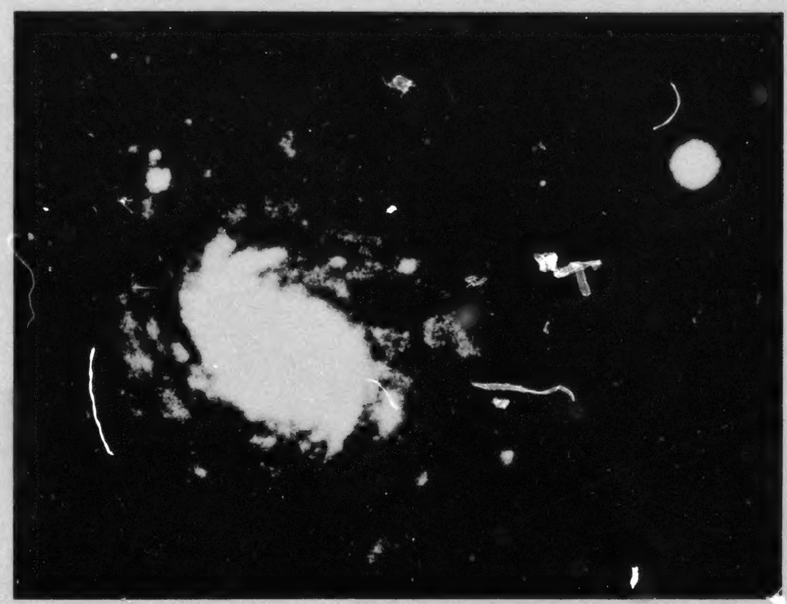
In December 1973 Lewis E. Snyder of the University of Virginia and David Buhl of the National Radio Astronomy Observatory (NRAO) were using the NRAO 36-foot millimeter wave telescope located at Kitt Peak in Arizona to search the radio spectrum of certain astronomical sources. During the course of this search they discovered in the spectrum of the center of the Orion Nebula a previously unknown strong emission line with a peculiarly shaped profile. After establishing the frequency of this new line at 86.2 GHz, they contacted the microwave spectroscopy group at the National Bureau of Standards (NBS).

Frank Lovas and Donald Johnson of NBS suggested several possible molecular states that might be responsible for the observed emission line. Among these was a very highly excited state of silicon monoxide (SiO). This molecule has been known to be present in the interstellar medium as well as in certain types of stars. The excitation of the line required a temperature of at least 1,800° K., which seemed rather extraordinary considering that up to that time the largest excitation observed was 600° K. for the water (H_2O) maser.

A subsequent survey by Dr. Snyder, Dr. Buhl, and Norio Kaifu (NRAO/Univeristy of Tokyo) showed that the peculiar line appeared even more strongly in a number of well known red giant variable stars. At about this time Patrick Thaddeus and John Mather of the National Aeronautics and Space Administration, and a group from the University of Texas (Davis, Blain, Van Till, and Vanden Bout) used the 16-foot telescope at the Millimeter Wave Observatory in Texas to detect two other lines of excited silicon monoxide at 43 GHz, thus confirming the rather unusual high-temperature excitation for the original line discovered in Orion.

The situation became even more startling when Drs. Buhl and Snyder, along with Drs. Lovas and Johnson, discovered during a June 1974 observing run that the second vibrationally excited state was sometimes just as strong as the first (this state requires a temperature of 3,600°K. to excite it). To add to the dilemma, emission from the unexcited (or ground) state and from an even more highly excited, or hotter, state was not detectable.

The most reasonable explanation of the enhanced intensity of the intermediately excited lines, and the complete absence of the unexcited and more highly excited lines, is that the observed lines are due to maser action within a shell of dust and gas around a red giant star. The star, at a surface temperature of 2,000°K., is pumping energy into the system which, in turn, is radiating in a maser mode. Thus SiO joins three other molecules, H_2O, CH, and OH, as known natural masers. The mechanism by which the star's energy is converted by the SiO molecules to these particular frequencies is not yet understood, but with two lines available for study and with an energy source that is well understood—such as the giant stars—this puzzle has a good chance of being solved in the next year or two.



The spiral Seyfert galaxy NGC 1068 is unusual in that most of its radiation is being emitted in the infrared wavelengths from a nucleus that is small compared to the total size of the galaxy. This photograph was taken with visible light. [Photo by Hale Observatories]

The Amazing Seyfert Galaxy NGC 1068

The infrared study of astronomical objects has been a small but increasingly important part of astronomy for the past several years. The field is a difficult one technically, but offers great promise for future observations. It is now known that many ordinary and unusual objects in the sky emit strongly in the infrared, and only by understanding the origin of the infrared radiation can we know the physical nature of such objects. The characteristic black body radiation of the Moon, the planets, cool stellar and galactic objects, and many galaxies and quasars is in the infrared region.

An example of a galaxy emitting infrared radiation is the Seyfert galaxy NGC 1068. This is a spiral galaxy with a bright inner region and a less luminous outer region. Dust lanes (dark areas) and spiral areas can be seen easily, and faint external spiral arms can also be traced. The amazing feature of this galaxy is that it is now known to be emitting most of its radiation in the infrared wavelengths from a nucleus that is small compared to the total size of the galaxy.

This Seyfert galaxy is being studied intensively, and scientists at the Universities of Arizona, California, Minnesota, and Texas, and the California Institute of Technology have made significant observations. The facilities used for the infrared observations were the telescope designed for infrared observations at Mount Lemmon, near Tucson, Ariz., and the Hale Observatory telescopes, including the 200-inch telescope on Palomar Mountain in California.

One of the most important observations is to measure the angular size of the emitting region, and therefore deduce the linear size. The linear size is needed to decide whether the emission arises from a thermal or nonthermal mechanism of energy generation. A large core would imply that the emission is thermal radiation from heated dust. A small core would imply a single very hot source, or perhaps several small sources, arising from self-absorbed synchrotron radiation.

The current observations of NGC 1068 show some very interesting properties. The size of the core, using observations at 10 microns, has been measured to be about 1 second of arc. At the assumed distance of NGC 1068, the core would be about 200 light years in size, which is in agreement with the size of the core measured in visible light. The radiation from such a large core is thus probably thermal and from heated dust grains. Spectral analysis of the radiation from the core fails to reveal any strong special features in the region from 2 to 18 microns, and there is a rapid cutoff in the energy distribution beyond 20 microns, which also implies thermal emission from dust particles. The measurements do not rule out a small amount of nonthermal emission, perhaps a quarter of the radiation, from an unresolved core.

MATHEMATICS

Hydrodynamic Stability

The need to understand the motions of fluids has been the motivation for a great deal of scientific research over the ages and is one of the cornerstones of applied mathematics. One of the important questions is that of hydrodynamic stability. If a small disturbance leaves the motions of a fluid system essentially unchanged, the system is called stable. If, on the other hand, small disturbances cause a change in the state of a system, the system is called unstable.

Consider the motions of a fluid of constant density, which may be described by nonlinear equations (the Navier-Stokes equations) and the equation of conservation of mass. If the exact solution of the system and appropriate boundary conditions are given, one may ask if the system is stable or unstable. To answer that, one must determine the conditions for stability. The state of the system is determined by an externally controllable quantity, the Reynolds number, R (for example, if a liquid is stirred, R is some measure of the stirring rate). The general problem is to find a critical value, R_C, of the Reynolds number such that when R is less than R_C, the flow is stable, and when R is greater than R_C, the system is unstable. Since the Navier-Stokes equations are quite complicated, exact solutions to the equations are unknown in physically realizable cases. The objective of the theory, then, is to obtain a lower bound, R_e, on the critical Reynolds number, R_C, for disturbances of arbitrary size; that is, the existence of a number R_e gives a sufficient condition for the stability (such that R is less than R_e) of the given flow.

Previously, a criterion was established for *steady* flows that can be contained in a strip of *finite* width. However, a certain mathematical condition (Poincare inequality) used in the proof of this criterion is violated if the flow has infinite extent, and the proof fails. Furthermore, when the flow is time dependent, this method requires that the disturbances decay at every instant.

Supported by an NSF grant at Johns Hopkins University, S.H. Davis and C. Von Kerczek have developed a technique to extract an improved stability theorem without using the Poincare inequality. Hence, asymptotic stability in the mean can be proved for R less than R_e, even for infinite domains. More important, the criterion gives a larger value of R_e for time-dependent states, since disturbances may grow at any instant but must decay "on the average" when R is less than R_e. This means a less conservative sufficient condition for stability is obtained. This theorem has already been used by G.M. Homsly in the case of modulated Benard convection and found to lead to significant improvement.

BIOLOGICAL AND MEDICAL SCIENCES

Support of basic research in the biological sciences has continued across a broad spectrum, enlarging our knowledge of the molecular and atomic basis of biological mechanisms and the more complex relations which appear in the intricate assemblies of cell organelles such as membranes and chromosomes, and enlarging our knowledge of cells themselves or collections of cells. At the other end of the spectrum, progress is being made in describing complex mental processes by examining ways in which sensory stimuli are processed and responses generated in the central nervous system. At all levels, research in biology continues to be characterized by an increasing demand for quantitative measurement and for protocols framed in clearly testable hypotheses.

Although the increasing rigor of biological research augers well for continued progress, it also makes the inadequacy of present knowledge more evident. The extent to which problems of food and health have been partially resolved for parts of the world population has made the need to solve them for all the world seem both more possible and more urgent. These same successes have, however, helped to create new problems. Rapidly increasing populations and aspirations which may outrun available supplies of energy and nonrenewable resources, and which lead to environmental degradation, may seriously threaten the renewable resource base of the biosphere. Man's ability to manipulate his environment has outstripped his development of the knowledge needed to manage these manipulations wisely. Although improved technology may provide tentative answers for present shortages, the technologies to be used in the long run will depend upon biological consequences which cannot now be predicted with any precision. A great deal more attention will have to be directed to applied research in biology, which seeks to find the best answer within the limitations of current knowledge. At least equally important is a much more rapid expansion of the basic understanding of the interactions in complex biological systems, and the development of a much sounder understanding of human beings and the factors that shape our aspirations and behavior.

Responses to these needs of necessity have been limited in fiscal year 1974, but continuing attention is given to ways in which the biological sciences program might be more responsive to the needs and opportunities in basic research. Progress made under the International Biological Program has made it clear that a strong effort should continue in the examination of ecological processes within a systems framework. Consequently, the Ecosystem Analysis Program will continue to play a very significant role in the activities of the division.

In response to the continued need to maintain an essential information base represented by systematic collections of flora and fauna and to the positive steps taken by the Association of Systematic Collections to develop a responsive and rational plan for these resources, a new Biological Resources Program has been established within the division. This program will also have the responsibility for genetic stock centers and for assessing needs for field research facilities and research natural areas.

The examples of research progress which follow present only a small sample of divisional activities and lines of research which will be particularly significant in the future.

Predation, Polymorphism, and Survival

In a lake ecosystem, energy is passed up the food chain from algae to small animals to fish. Scientists have begun only recently to recognize the complex effects that predatory habits have on the composition of the prey species in lakes. The following studies have provided new insights on the species variation observed for a lake population of microscopic planktonic animals.

Within the Lake Washington population of a minute crustacean zooplankton, *Bosmina longirostris*, W.T. Edmonson, and W. Charles Kerfoot of the University of Washington have been studying an interesting spatial and temporal pattern of polymorphism similar to patterns observable in other lakes. These patterns have long been a puzzle to biologists, and the recent work of the Edmonson-Kerfoot team provides the explanation, previously unconsidered, that they result from the differential effect of two classes of predation.

The different kinds of body forms of *Bosmina* are found in different parts of the lake in the fall of the year. The open-water population is the "long-featured" morph, characterized by longer projections of body parts, such as antennule, larger eye, and a relatively larger size at maturity. The "short-featured" form found inshore is characterized by shorter projections, smaller eye, and a slightly smaller size at maturity.

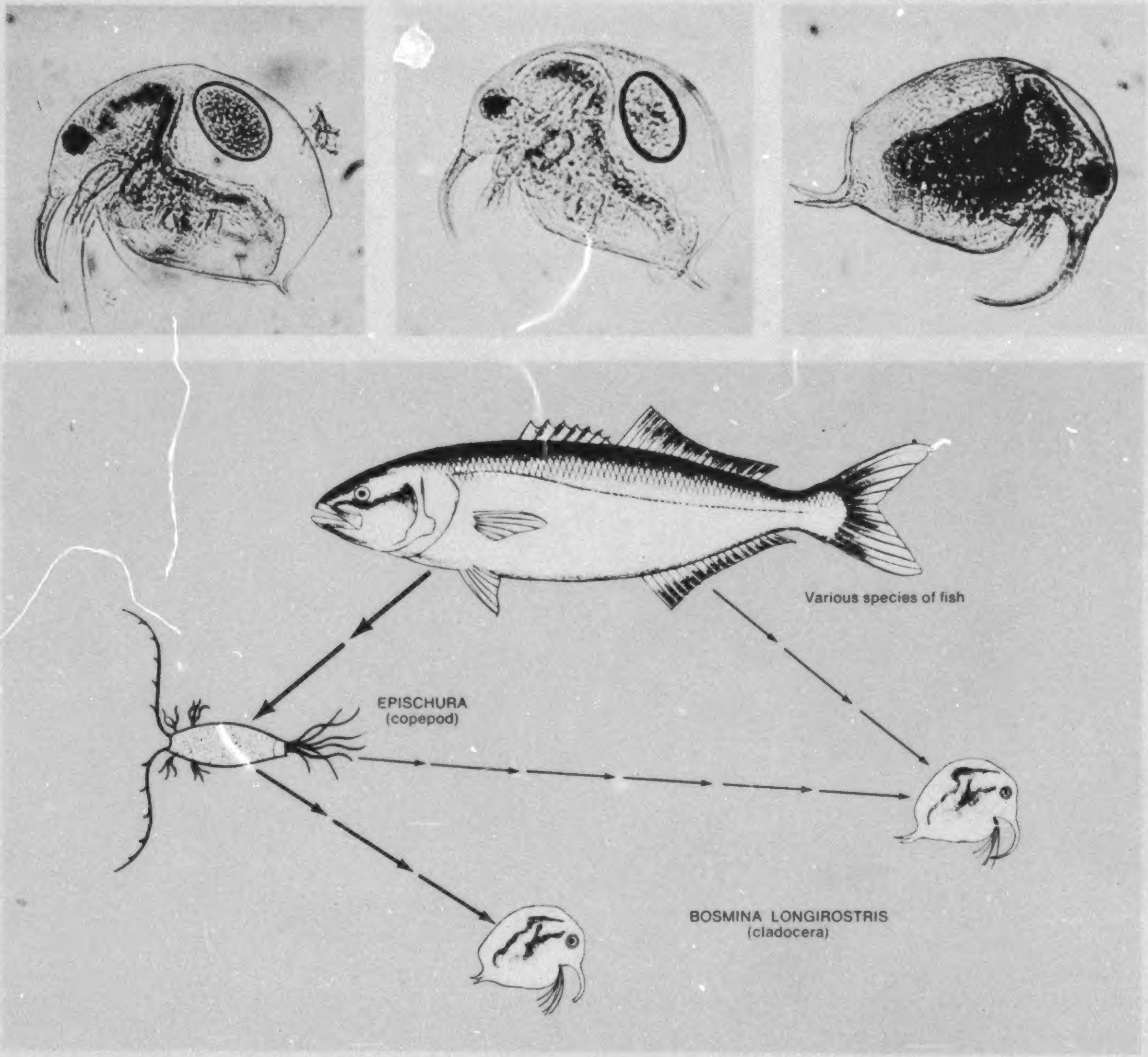
The long-featured population is found in open water throughout the year; the inshore population changes seasonally. In early spring, when the *Bosmina* population increases rapidly from its wintertime scarcity, short-featured morphs are found in shallow water, but many more individuals are intermediate between the two extremes. As spring becomes summer, the intermediates disappear and only short-featured individuals are formed inshore. The intermediate forms so abundant in spring are thought to be the products of sexual crosses between clones that occurred during the preceding autumn. The sexually fertilized eggs, quiescent over the winter, develop and hatch in early spring.

Under laboratory culture each morph reproduces itself and each can be considered a clone of genetically identical individuals since under these conditions *Bosmina* populations are comprised of females that produce diploid eggs that do not require fertilization in order to develop. In predator-free laboratory populations of mixtures of the three forms, the rapidly reproducing intermediate morph will quickly replace both types of extremes, illustrating that they are more competitive and efficient in converting algae and available nutrients to growth materials. But in the lake, survival depends more on the ability to escape predation than on metabolic efficiency.

The late season dominance of the two extreme morphs of *Bosmina* in different parts of the lake is the result of two quite different kinds of predation. One is the visual selection of individual prey by young fish in the shallows. The other is the blind, grasping predation by the large copepod *Epischura* that inhabits the open waters of the lake. *Epischura* glides through the water until it encounters an object. It then grasps the prey and attempts to tear it apart and eat it. The longer projections of *Bosmina* are more difficult for the copepod to reorient and consume than the short-featured morph.

When an *Epischura* is added to an experimental mixture of intermediates and the two extreme morphs in about equal proportions, the short-featured morphs are quickly eliminated, leaving mostly long-featured morphs together with a few intermediates. The dominance of the long-featured morph in the open waters is, therefore, interpreted as the result of preferential removal by *Epischura* of the other two more easily eaten morphs. The larger fish in the open water of the lake do not feed on the small *Bosmina*, preferring *Epischura* itself, or other large species of animal plankton.

On the other hand, studies of schools of young fish in the lake show preferential feeding on the larger, long-featured morph, leaving the other forms to dominate when the school has swum away. The seasonal shift in the composition of the *Bosmina longirostris* population in inshore waters is, therefore, interpreted as the result of visual predation by the immense number of young



The changing distribution of various life forms in lakes at different times of the year has not been clearly understood. Now the role of predators is being recognized as a factor bringing about such changes. Studies of different varieties of a tiny crustacean found in different parts of Lake Washington at different seasons show that the distributions of these polymorphs depend on the effects of two kinds of predators—copepods and fish. In early spring, all forms of the crustacean *Bosmina* are found in inshore shallow waters—the short-featured (top left), intermediate (top middle), and long (top right). As spring turns into summer, the intermediate-size morphs are eaten by both copepods and fish and gradually disappear. The long-featured form is also cleared from shallow waters early in the year by small fish which overlook the short forms. Thus, by summer, the short *Bosmina* are the dominant forms. In open waters of the middle of the lake, long-form *Bosmina* are found throughout the year. By late summer this is the dominating form in open water, mostly as a result of the preference of copepods for small morphs, and of the preference of fish for copepods. A diagram of the preferred eating patterns of fish and copepods is shown on the right. The degree of preference is shown by the strength of the arrows. [Photos by W. Charles Kerfoot] fish which develop in the weedbeds covering the shallow bottom. These young fish quickly eliminate any *Epischura* and other large plankton, and then progressively remove all forms of *Bosmina* except the small, short-featured morph.

Clones of each extreme morph survive summer predation in different parts of the lake, while the intermediate size preyed upon by both young fish and the copepod *Epischura* is virtually eliminated by autumn. As winter approaches, males and females appear in both clones and with the vigorous mixing of inshore and offshore water have the opportunity for crossbreeding, and numerous intermediate progeny hatch in the spring. The demonstrated competitive success of this swarm of intermediates establishes the spring population of zooplankton.

Neural Processes

Understanding how the brain functions in perception, in storing information, and in thinking is one of the most difficult challenges facing biologists. Recent progress from the laboratory of Roger N. Shepard of Stanford University provides new insight into the nature of the human mind. His work is directed toward an analysis of the internal representation processes that we call memory and imagination images. The results of his experiments indicate that some of these internal processes operate by an analog process in which memory images are stored in picturelike form. Dr. Shepard has shown that when one rotates the mental image of an object from one position to another, the mental image is in fact going through all the intermediate positions of the rotation. That is, the parts and the relationships among the parts of the image are transformed continuously in accordance with the mental rotation. This finding is far reaching in that it challenges the traditional view that the representation of an object in memory is in terms of discrete, languagelike representations such as the hierarchical sets of features that have been proposed in most computer simulations.

The following studies from Dr. Shepard's laboratory illustrate the bases of the above interpretation. Individuals were asked to identify number and letter symbols as normal or as mirror images when the symbols were presented in various orientations in the plane from 0° to 180° (upright, tilted, or upside down). For example, individuals were required to determine whether the presented letter was a normal "R" or a mirror image letter "Я," regardless of its orientation in the plane. Normal and mirror image alphanumeric symbols were presented equally frequently. Reaction time measurements indicated that the required "match-mismatch" discrimination is made by rotating a mental image of the presented symbol into its normal upright orientation or into an abnormally rotated orientation that an individual had been led to expect. Reaction times turned out to be a remarkably linear function of the angular difference between actually presented and expected orientations of a symbol. Furthermore, Dr. Shepard found that the time required to mentally rotate an image from orientation A to orientation C is the sum of the times required to rotate from A to some intermediate orientation B, and to rotate from B to C.

Dr. Shepard has also found that it does not matter whether the mental rotation is carried out in the presence of an external stimulus, or in the absence of the stimulus in preparation for it. If information as to both the identity and orientation of a stimulus is provided sufficiently in advance (e.g., the letter "R" at 120° clockwise), an image of a normal "R" is mentally rotated into the designated orientation for rapid comparison with the stimulus when it appears. Thus, when individuals were set for a specific alphanumeric symbol in a specific orientation, reaction times for determining whether it was a normal or mirror image symbol were consistently short and independent of the angle of the expected orientation. Individuals are only able to carry out the mental rotation of an internal representation of a particular concrete object—not a general abstract frame of reference. Thus, even though an individual is given advance information as to the orientation of an upcoming stimulus (e.g., 120° clockwise), he is not able to perform an advance mental rotation unless he also knows the identity of the stimulus.

These and other studies from Dr. Shepard's laboratory indicate that in mentally rotating the image of an object, the internal structure of the image is transformed in a way that corresponds specifically to the transformations that occur in a rotation of a physical object. To account for these results requires a postulation that either there are neural mechanisms that store images in picturelike form (e.g., neural holograms) or that neural mechanisms exist that can take language-like stored descriptions and construct picturelike images from them.

In studies of brain centers of higher animals, researchers have made significant progress in dealing with the complexity of interrelated structures and nerve networks of the mammalian brain. Studies of neural processes in higher order brain centers for the past 50 years have been characterized by a "single-unit" approach, i.e., the examination of electrophysiological properties of neurons one by one. Much useful information has resulted, but the single-unit approach is inherently limited to the capture of static, simple geometric properties of neuronal activity. Nearly all forms of interaction between neurons or any sequential patterning must escape detection. One viable alternative has been the analysis of the gross potentials of the brain with instruments such as the electroencephalogram and the electroretinogram, as well as with evoked brain potentials. However, in the view of many scientists there is not yet enough known about the underlying interactions to be able to interpret these gross potentials meaningfully.

Until recently, this paradox, i.e., the static limitations of the single-unit approach vis-a-vis the difficulty in interpreting gross potentials, seemed unresolvable. A grantee from the University of Pittsburgh, Gerhard Werner, in recent research has transcended the inherent limitations of the single-unit techniques by developing a 4 by 4 multielectrode array; he has been successful in recording simultaneously from as many as 16 neurons. Piezoelectric transducers were built to enable separate positioning and automated advance of each recording microelectrode. Special computer techniques were developed to analyze the large amounts of data recorded. These arrays are being used to study the patterning of nerve responses in brain centers when various stimuli are applied to the skin. Dr. Werner already has shown that complex temporal and spatial patterns of activity do exist. Research with this small array is being continued while a 64 by 64 electrode array is being constructed. Thus, for the first time, complex temporal and spatial neural interactions can be analyzed with an approach using appropriately complex measurements. We anticipate that other investigators will follow Dr. Werner's lead. For example, it now will be possible to analyze brain potentials by simultaneously recording and interrelating both the gross potential and underlying neuronal activity. The combined information should greatly extend our ability to interpret neural interactions and patterns of the higher brain centers.

Powerful new research tools and significant findings on the molecular working of the brain are emerging from the research of Stephen Heinemann of the Salk Institute for Biological Studies, San Diego, Calif. The long-term aim of this research is to understand, at the molecular level, how the brain operates. Since in many instances it is impossible to study the development and function of the nervous system in living intact animals, it is essential to have relatively simple systems which can be analyzed and manipulated outside the body.

Dr. Heinemann, in collaboration with other investigators, has developed a tissue culture system adapted to continuous growth which maintains its ability to form synapses—the areas where a neuron transmits information to another neuron. Cell lines of both nerve and muscle have been established and grow in the same culture environment with the formation of synapses. These cells have many of the electrical, pharmacological, and biochemical properties of intact cells. Since the cells grow as monolayers in glass dishes, they are readily available for study by a wide variety of techniques. The nutritional and physical environment can be altered as desired. Intracellular and hormonal interactions can be investigated in relation to cell growth and synapse formation. Using techniques of time-lapse photography and electrophysiology, researchers should be able to define the stages in synapse development over extended periods of time. The cells can be penetrated with microelectrodes or micropipettes for intracellular recording while being watched by phase contrast microscopy. In addition, the opportunity exists to select mutant cell lines deficient in a selected property. When these cell lines are introduced into the tissue culture system, the spectrum of available study material increases.

The availability of this system, adapted to neurobiological research, represents a significant step toward using the tools of genetics, biochemistry, biophysics, and immunology to increase scientific knowledge as to how cells develop and respond to stimuli, how the nervous system operates at the molecular level, and potentially the basis of a wide range of debilitating neuromuscular diseases.

Cells and Genes

Cell membranes play a critical role in many essential biological processes, particularly with respect to intracellular regulation by controlling the molecules that enter and leave cells and by mediating the interactions between cells. Membranes are sites of highly organized assemblies of macromolecules, but relatively little is known about their molecular organization and dynamic state, a necessary prerequisite for understanding how cells function. Recent studies by M. Edidin, S. Roth, and L. Brand of Johns Hopkins University have employed nanosecond and steady-state fluorescence spectroscopy to analyze the spatial relation of molecules and their motion at the cell surface as related to functions of the cell. These studies involve attaching small fluorescent molecules to specific antigens and following the spatial association and movement at the cell surface. Their results show that there are a large number of antigenic sites distributed over the entire cell surface and that they move in the plane of the membrane to one pole of the cell accompanied by a ruffling movement of the membrane. Continuation of these studies coupled with studies of other types of cell surface sites should reveal the extent to which the membrane approximates a fluid rather than a solid.

One aspect of biological processes is developmental biology—the study of those striking changes that occur in organisms from their inception as zygotes until their maturation as adults. Some of these changes are unique to each species while others are more general, even universal, in character and are found in all organisms.

One of the universal features of development is the production of messenger RNA (mRNA). The mRNA is the vital link between the genetic information contained in DNA and the production of protein necessary for growth. Leon Dure of the University of Georgia is studying the relation of mRNA production and seed maturation and germination. In higher plants the embryo begins to develop and then ceases growth as the seed matures. The seed is a remarkable survival package, complete with protective covering, stored food reserves, and a dormant but living embryo. A vital question in plant development is what causes the embryo to stop developing and become dormant. An equally important question is what changes trigger this dormancy to be broken and stimulate the embryo to grow into a mature plant as the seed germinates.

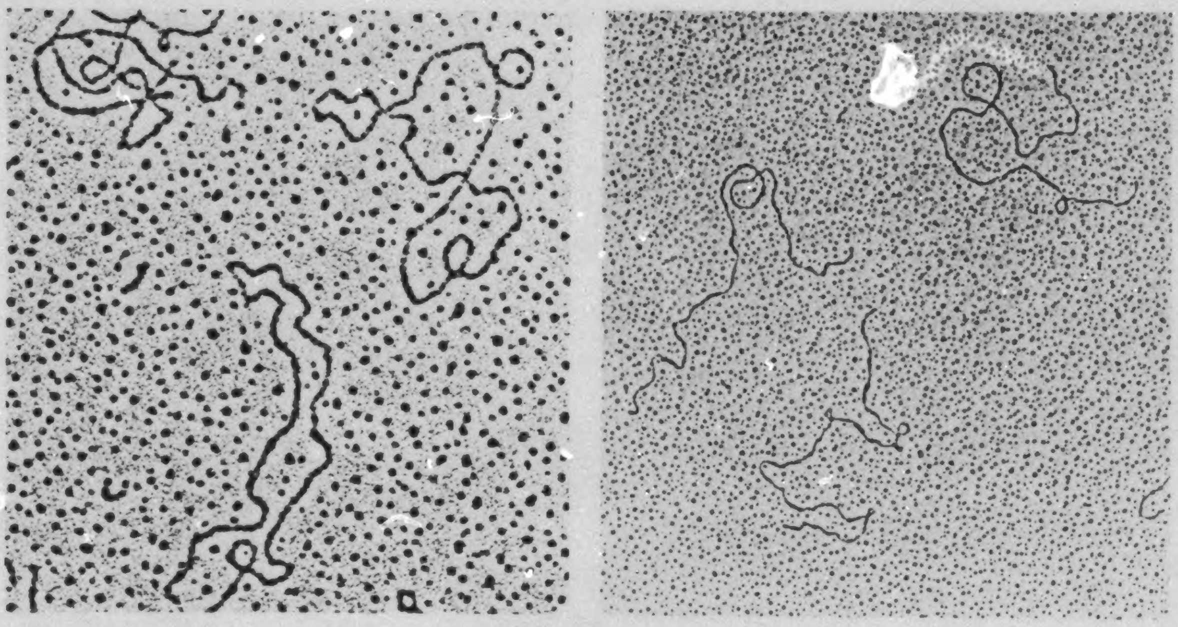
Dr. Dure has found that mRNA has a critical role in these events. Working with cotton, he found that a large body of mRNA is synthesized in late embryogenesis; translation of this mRNA genetic information will inaugurate seed germination. Moreover, a plant growth regulator, abscisic acid, acts to prevent premature functioning of the mRNA until the mature, dessicated seed is formed. For the seed to germinate, the concentration of abscisic acid must be lowered until it no longer inhibits mRNA translation. Dr. Dure has also shown that during the early stages of seed germination, the mRNA produced before the embryo becomes dormant is used for protein synthesis. Thus, the critical stage of seed germination can occur without the complete involvement of the genetic store itself.

Specific questions in biology are often best answered by seeking a simple system for study. Thus, less complicated organisms, such as the slime mold *Dictyostelium*, can provide important information on mRNA synthesis and its function in specific protein synthesis. This is the organism used by Harvey Lodish at MIT to study mRNA synthesis and function during development. This organism has a stage during which it migrates. During this stage 30 percent of the protein synthesized is in the form of a molecule, tentatively identified as actin. (This observation is of interest since actin is known to be associated with movement in many animals.) Dr. Lodish intends to purify the mRNA responsible for actin synthesis and, having this, to synthesize the DNA segment responsible for the production of the actin mRNA *in vitro*. Such a system will permit a detailed analysis of the factors regulating production of specific mRNA's. Clearly, this type of information is likely to aid Dr. Dure in devising experiments on more complex plant embryos.

A new advance in genetic manipulation has come into existence this past year. It now appears possible to transfer genes from any organism into the simple bacterium, *E. coli*. This development should allow for extending our knowledge on the molecular organization of the genetic material of higher organisms, and is likely to find eventual practical applications. For example, *E. coli* could be programmed to produce antibiotics by transplanting genes from fungi which code for antibiotic production, or even eventually to produce human insulin after transplanting the correct human genes.

The recent developments which have made these exciting possibilities real are twofold: "restriction" enzymes, which have been shown to split the genetic molecule, DNA, only at specific sites; and transformation in *E. coli*. Transformation is a process, existing in some bacteria, whereby the genes from one bacterium, in the form of pure isolated DNA, can be transferred to another bacterium. Michio Oishi at the Public Health Research Institute of New York developed the conditions and strains to allow transformation in *E. coli*. Stanley N. Cohen of Stanford University has devised ingenious ways to introduce foreign genes by transformation into *E. coli*. Dr. Cohen for some years has been studying the plasmids of *E. coli*. Most *E. coli* genes are contained on a long circular molecule of DNA (the chromosome). The plasmids represent a class of much shorter circular DNA molecules containing many fewer genes which are, in general, not essential to the life of the cell. Some of these plasmids contain genes which render the cell resistant to antibiotics (indeed, the plasmids are probably responsible for the resistance to many antibiotics among pathogenic bacteria found in the world today). Dr. Cohen, in collaboration with several colleagues, used a particular restriction enzyme which splits the plasmid DNA at only one site. The plasmid DNA also carries a gene for resistance to tetracycline. Using various methods of modern molecular biology, he inserted foreign genes from the DNA of other organisms, similarly split with the same enzyme. He then selected those *E. coli* which had been successfully transformed with this "hybrid" plasmid DNA by challenging them with the antibiotic; only those carrying the plasmid with the tetracycline-resistant gene can survive this treatment. Dr. Cohen and his associates used these methods to introduce specific genes from an animal (a toad). They have shown that the hybrid plasmid reproducing in *E. coli* contained the original plasmid DNA and the animal DNA and, furthermore, that the animal genes were functional.

The implications of this work are vast, yet the techniques are relatively simple. The stumbling blocks for further work revolve around the difficulties of selecting easily the desired genes to transplant into *E. coli* from among the very large amount of DNA contained in the cells of higher organisms. Dr. Cohen took advantage of a special property of the African toad which allows ready isolation of a specific class of genes. David Hogness, also of Stanford, has circumvented this difficulty by identifying genes from the fruit fly *Drosophila*, after growth in *E. coli*. After construction of hybrid plasmids containing unselected fragments of *Drosophila* DNA and introduction of these plasmids into *E. coli*, single transformed *E. coli* cells are grown to large numbers, and their



Electron micrographs show circular, untreated molecules of a plasmid DNA (left) used by Stanley Cohen at Stanford in experiments to introduce foreign DNA into *E. coli* DNA. After treatment with a particular restriction enzyme, linear full-length plasmid DNA molecules are obtained (right), indicating that breaks have occurred at only one site on each molecule. (Photos by Stanley Cohen)

plasmids re-isolated. These reproduced hybrid plasmids are reacted with the chromosomes of *Drosophila* where they will interact only with DNA complementary to the *Drosophila* DNA present in the hybrid plasmid. The beauty of *Drosophila*, which has been under intensive genetic study since the turn of the century, is that the genetic map has been identified with the visual appearance of the giant chromosomes existing in certain specialized cells. It has so far been possible to identify at least 20 different isolates in which *Drosophila* genes have been introduced into a particular *E. coli* cell. Any region of the *Drosophila* gene can later be recovered from the plasmid by treating the hybrid plasmid with the same restriction enzyme, which will now have two sites of attack, one on either side of the inserted gene. The purified *Drosophila* genetic material can now be studied from many angles. Further progress for understanding complex genetic systems is anticipated.

These gene transfer techniques present exciting possibilities for agricultural and medical applications. Medical applications, however, must await more advanced knowledge about human chromosomes. Increasing numbers of inherited diseases have been shown to be associated with mutations in particular genes, but the complexities of the chromosomes are such that progress in eliminating or overcoming them will be slow. However, the gene transfer techniques should in the near future prove to be a real breakthrough in the genetic manipulation of plants and microorganisms for enhanced food and fuel production.

The great power of this new approach, however, is not without potential hazard. Mindful of this, a group of distinguished scientists who have been at the forefront of this field (including Drs. Cohen and Hogness) have voluntarily suspended research in the instances of gene transfers involving animal tumor viruses and some classes of antibiotic-resistant bacteria. Furthermore, they have urged that other scientists join in the moratorium and with the encouragement of both the National Academy of Sciences and NSF are organizing an international conference to assess hazards and to develop effective guidelines for this type of work.

ENVIRONMENTAL SCIENCES

Environmental sciences had their beginnings in attempts to explain phenomena of the solid Earth, the oceans, and the atmosphere that directly impinge on man and his everyday life. Research was developed on subjects such as soils, minerals, streams, tides, ocean currents, and the weather, as well as on infrequent events of extraordinary magnitude such as earthquakes, volcanic eruptions, and violent storms. The development of the ability to predict changes in these environmental phenomena has required an understanding of the dynamics of natural processes and the manipulation of large volumes of data.

Although many features of the Earth, oceans, and atmosphere can be studied locally, or even in the laboratory, complete knowledge of some complex natural systems requires observations and experiments on regional or even global scales. Recent trends in environmental science research have been toward coordinated large-scale programs that involve the combined efforts of many organizations and individuals. Fiscal year 1974 was marked by substantial progress in several such coordinated programs.

The most important event of 1974 in the Atmospheric Sciences Section research was the initiation of a massive investigation of the atmosphere and ocean centered in the equatorial Atlantic Ocean. This study, under the auspices of the Global Atmospheric Research Program (GARP), is the GARP Atlantic Tropical Experiment (GATE), involving scientists from more than 70 nations, using 40 ships, a dozen aircraft, balloons, ground stations, and a geostationary weather satellite. The experiment, more than 10 years in planning, is expected to provide much new information about the behavior of the tropical atmosphere and its ultimate effects of global weather.

Another cooperative program moved forward with the establishment in the Atmospheric Sciences Section of a Coordination Office for the International Magnetospheric Study, a 3-year program starting in 1976. Scientists from a number of countries will coordinate measurements from ground-based facilities, aircraft, balloons, rockets, and spacecraft in order to provide comprehensive and quantitative knowledge about the dynamics of processes operating on plasmas in the geomagnetic fields surrounding the Earth.

The National Hail Research Experiment, a 5-year program managed by the National Center for Atmospheric Research, aims at improving the understanding of hail and severe storms and at exploring methods for the artificial inhibition of hail. The third field experiment in the summer of 1974 was centered in northeastern Colorado, using ground-based radar, armored aircraft, sailplanes, rockets, and dropsondes. Several university groups participated, supported by the Division of Environmental Sciences.

A cooperative project in 1974 in the Earth Sciences Section was the U.S./U.S.S.R. Cooperative Program for Research in Earthquake Prediction, authorized under the Environmental Protection Agreement between the two countries. Grants were made to scientists from four universities and the U.S. Geological Survey to provide the U.S. share of an exchange of geophysicists between this country and the U.S.S.R. Detailed studies are under way, particularly in the Garm region of Russia and along the San Andreas fault in California, to learn more about the mechanisms of certain types of earthquakes and to compare equipment and seismically active areas.

An interagency *ad hoc* committee on geodynamics was set up by the U.S. Government in 1974 to coordinate participation in the International Geodynamics Project. The project, which involves 50 countries and will extend for 6 years, is aimed at further testing the plate tectonics model as a concept for explaining the interrelationships between the movements of the few large plates making up the surface of the Earth. It also will test the plate tectonics concept in the origin of earthquakes and volcanoes, the building of mountains, origin of ocean basins, formation of ore deposits, and other related phenomena. Almost all aspects of earth sciences are included.

Oceanographic research, by its very nature, tends to create cooperation among agencies because of the limited availability of research platforms. Most work supported by the Oceanography Section is performed by a few oceanographic institutions. A major international project, the French-American Mid-Ocean Undersea Study (FAMOUS), has as its objective an investigation of the processes by which ocean floor material is formed at the spreading zones along a portion of the mid-Atlantic Ridge. Begun in 1971, the early phases included studies with ships and aircraft to identify the most promising locations for the detailed studies with French and American submersibles that began late in fiscal year 1974.

A smaller project that involved the cooperation of three oceanographic institutions was the shelf dynamics program in the eastern part of the Gulf of Mexico. The purpose was primarily to develop numerical models, based on field measurements, that would help to understand and predict the complex circulation patterns of water on shallow continental shelves. The preliminary results have been promising, and may ultimately lead to a more detailed program.

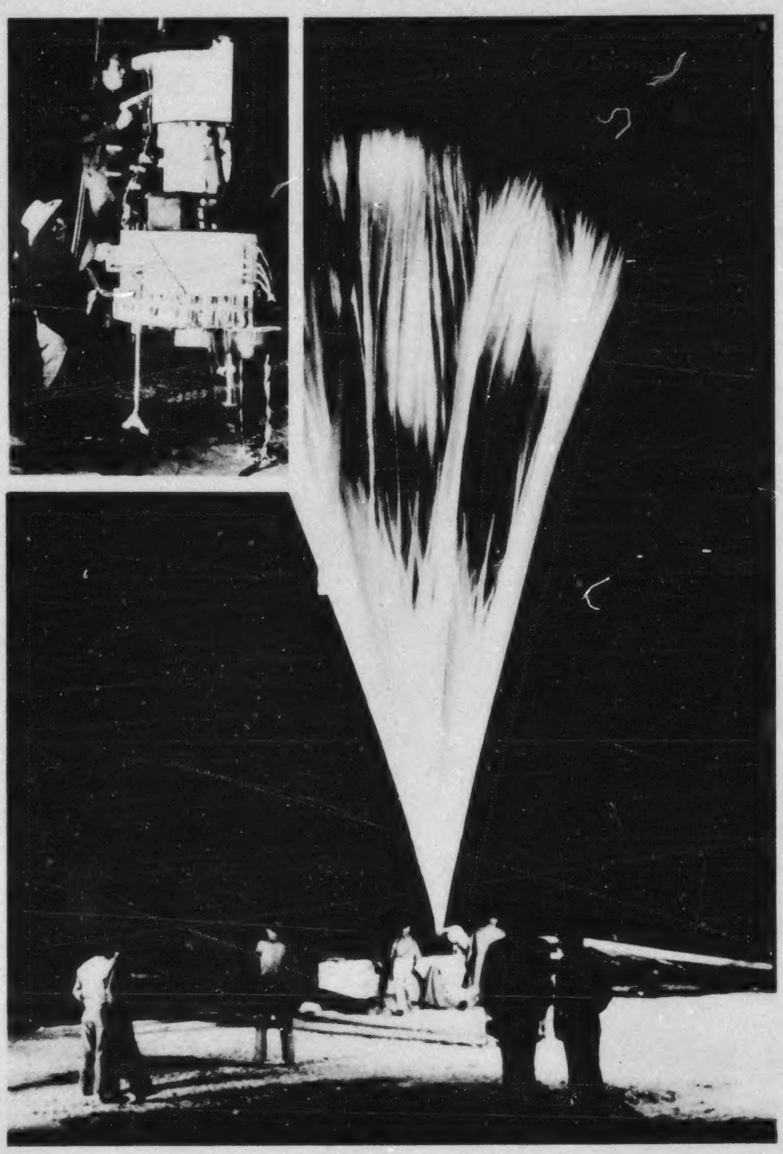
ATMOSPHERIC SCIENCES

Composition of the Stratosphere

In anticipation of eventual renewed debate over the SST, scientists at the National Center for Atmospheric Research (NCAR) brought experimental and theoretical techniques to bear on questions of the natural composition of the stratosphere and possible impacts of manmade alterations on human health and climate stability. Studies are under way on the composition and transport of trace gases in the stratosphere and on processes that could lower stratospheric ozone concentrations and raise or lower aerosol concentrations.

A technique to increase the variety and volume of direct measurements of trace gases in the stratosphere was developed and successfully tested in September 1973. A cryogenic sampler, flown aboard a stratospheric balloon, captured large air samples by condensing the air at low temperatures in vacuum bottles. Measurements showed vertical concentration profiles of hydrogen, methane, carbon monoxide and dioxide, and nitrous oxide—and allowed comparisons among these constituents. For the first time, reliable measurements of hydrogen and carbon dioxide were made, and carbon monoxide and nitrous oxide were found at altitudes of 35 kilometers—12 kilometers higher than detected before.

Another study gave the first solid evidence of nitric acid vapor in the stratosphere. NCAR sampling equipment aboard U.S. Air Force WRB-57F aircraft (part of the Atomic Energy Commission's Project Airstream) gathered data in the stratosphere (12 to 19 kilometers) along continuous paths from northern Canada to southern Argentina. Supplementary balloon sampling flights were made to altitudes of 37 kilometers. Stratospheric nitric acid may be a key constituent in the catalytic reduction of ozone and the consequent raising of ultraviolet intensity at the Earth's surface. Measurements of sulfate—another important stratospheric constituent—showed that its concentration in the sulfate layer (about 20 kilometers) is lower than at higher altitudes. Sulfate distribu-



On May 5, 1974, an experimental balloon was launched by the National Center for Atmospheric Research to test remote sensing equipment for later use in satellites to obtain data on the composition and temperature of the Earth's lower atmosphere. The equipment, shown at right as it is being prepared for the launch, contains a device to be aimed across the edge of the Earth as seen from space. It can observe 60 times as much atmospheric gas as can vertically aimed remote sensors. [Photos by NCAR] tion is controlled largely by air motions, not by its own diffusion or sedimentation as previously believed. Evidence about the ways in which sulfate can spread toward the Equator from polar sources and migrate between the Northern and Southern Hemispheres indicates that sulfate remains in layers for a long time (up to a year). SST exhaust emissions would probably behave similarly.

A third experiment was the balloon flight of the Lower Atmosphere Composition and Temperature Experiment (LACATE)—a successful test of apparatus that will fly aboard the *Nimbus G* satellite later in the 1970's. LACATE, developed at NCAR, scans across the Earth's horizon and remotely measures the infrared radiation emitted by gases in the atmosphere. The test experiment, undertaken by Government agencies and three universities, yielded one of the most complete sets of data on the composition of the stratosphere obtained so far.

Theoreticians at NCAR made important steps in modeling the transport of stratospheric trace constituents to predict their speed and direction of distribution. One model accurately simulated the observed transport of radioactive bomb debris and the observed distribution of ozone. That model, and transport models in use elsewhere, will profit from new "objective analysis methods" developed at NCAR to convert weather balloon (radiosonde) data to a basic data set that supplies vertical data (while systematically correlating vertical and horizontal structures) that cannot be measured directly.

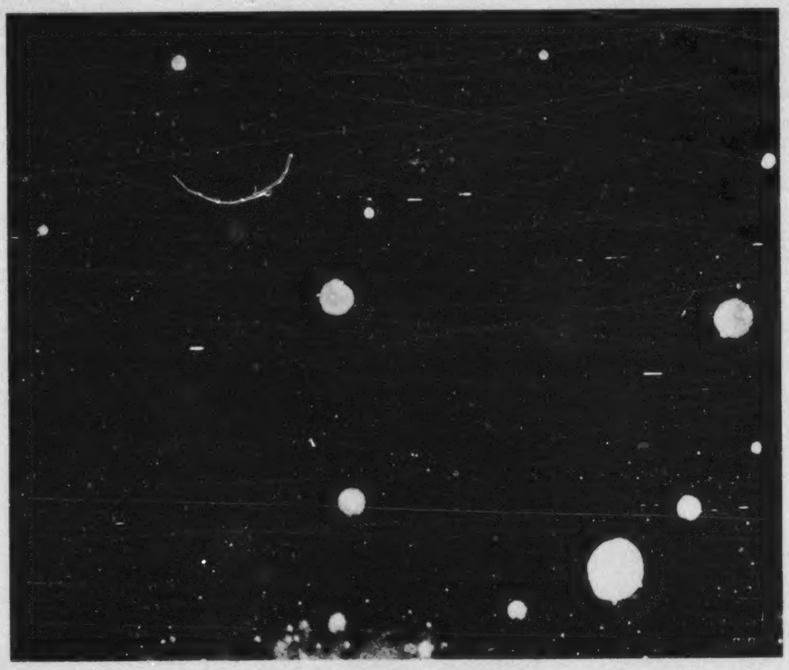
At the request of the Department of Transportation, which is sponsoring a Climatic Impact Assessments Program to elucidate all SST hazards, NCAR conducted a study of possible responses of ground surface temperature to aircraft-induced changes in stratospheric aerosols and ozone. A simple model suggested that altered aerosol concentrations might decrease surface temperatures by several degrees. Moreover, stratospheric *cooling* caused by decreased ozone might cause significant surface *warming*. These effects may be verified by a project now under way to construct a more complex radiative-convective equilibrium model for stratospheric studies.

Probing the Hailstorm

Progress toward clarification of the processes that produce hail and methods to prevent damaging hail emerged from the second field season of the National Hail Research Experiment (NHRE). Several universities and government and private agencies are participating in the multiyear experiment under National Center for Atmospheric Research (NCAR) management.

Combined studies from structural analysis of hailstones and flights of a sailplane above the freezing level of developing storms gave strong evidence that hailstones develop directly from the ice phase and not from the freezing of large (drizzle-sized), supercooled water droplets. Although the latter hypothesis is the basis of a Russian hail suppression program that has reported practical success, it does not appear to apply to Colorado storms. The distinction between the theories is important, since the locations and mechanisms of hailstone formation must be known to make effective use of cloud-seeding agents to convert a storm's moisture to smaller (nondamaging) hailstones and/or a greater proportion of rainfall.

NHRE radar techniques to detect early stages of hail growth have matured. Dual-wavelength measure-



Ice and water droplets, photographed from an NCAR sailplane above the freezing level of storm clouds, showed that ice particles far outnumbered large water droplets. Large dots in this photograph are ice particles; and small dots are supercooled water droplets with radii less than 10 microns. No large water droplets appear in this field of view. [Photo by NCAR] ments have provided the first unequivocal evidence of hail within a cloud and have also revealed hail trajectories in clouds, from which the extent of hailswaths at the ground may be deduced.

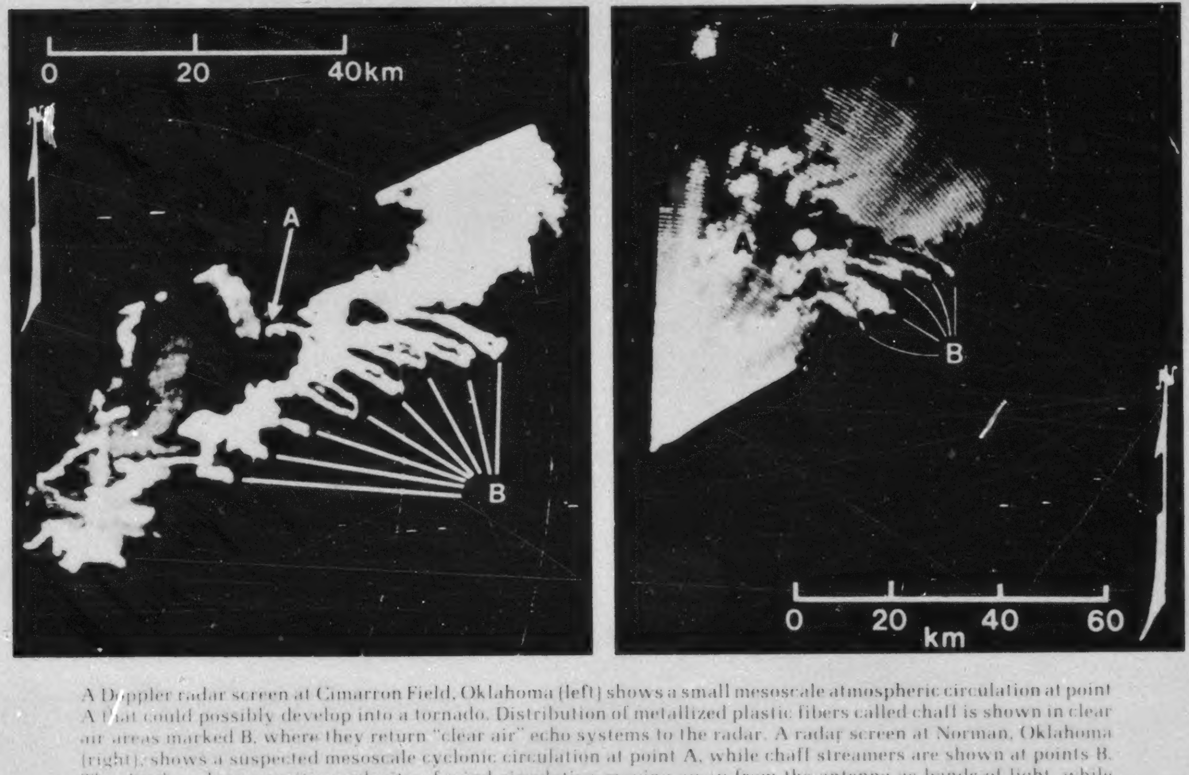
Interesting evidence about the masses and moisture budgets of hailstorms was another product of NHRE field studies. Analysis of a case-history storm showed an estimated 13 kilotons per second of water vapor entering the cloud base. The accounting for this amount of water vapor inflow includes 4.5 kilotons per second flowing out as vapor; about 2 kilotons per second—roughly equivalent to Niagara Falls—of rainout; with the remaining 6.5 kilotons per second being transported downwind in the cloud's anvil top. Rainfall from the anvil evaporates before reaching the ground. Strong winds aloft, accompanying conditions of high shear apparently act to transport large quantities of water downwind from the anvil. These factors are responsible for the low precipitation efficiency (about 15 percent) of the storm cloud. Familiar evidence of this process is the dense cirrus canopy that often covers the sky following strong convective activity.

Tornado Dynamics

John McCarthy at the University of Oklahoma, in cooperation with the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory (NSSL), has recently completed the first year of convection research in central Oklahoma. The primary objective is to understand the circulation and thermodynamic structure of tornado-producing thunderstorms.

Typically, a tornado funnel varies in diameter from 30 to 300 meters while embedded in a larger mesoscale cyclonic circulation ranging from 3 to 8 kilometers in diameter. This parent circulation is usually identified as a tornado cyclone, and is usually situated near the right rear flank of the thunderstorm. While the presence of such a mesoscale circulation by no means assures that a tornado will form, there does appear to be a high correlation between them.

Dr. McCarthy designed an experiment that uses a special radar reflective material called "chaff," a metallized plastic fiber, which, when distributed in clear air, will return "clear air" echo signals to the radar. When chaff is distributed through much of the volume of clear air adjacent to the natural echo of the meso-



A Doppler radar screen at Cimarron Field, Oklahoma (left) shows a small mesoscale atmospheric circulation at point A that could possibly develop into a tornado. Distribution of metallized plastic fibers called chaff is shown in clear air areas marked B, where they return "clear air" echo systems to the radar. A radar screen at Norman, Oklahoma (right), shows a suspected mesoscale cyclonic circulation at point A, while chaff streamers are shown at points B. The display shows positive velocity of wind circulation moving away from the antenna as bands of light, while negative velocity moving toward the antenna is shown as solid light. [Photos by John McCarthy] scale circulation, radars can see the entire circulation.

A number of excellent meteorological tools have been used in this research. The NSSL 10-centimeter Dual Doppler radar system, one located at Norman and another at Cimarron Field, 42 kilometers northwest of Norman, was the primary data acquisition tool. The chaff dispersal system was capable of distributing 10-centimeter chaff in five distinct bundles through a 2,600-meter vertical column below the airplane flight level.

The University of Wyoming meteorological research Queen Air airplane, operated under subcontract to the University of Oklahoma, provided a highly sophisticated measurement platform, as well as a means of delivering the chaff to the appropriate environmental inflow regions of a tornado cyclone.

On June 8, 1974, a severe thunderstorm containing a mesoscale circulation produced a tornado at Harrah, Okla. This storm was one of a number of similar storms occurring during a tornado outbreak in central Oklahoma on that day. Chaff operations were conducted before and during this particular tornadic storm.

While the storm was in its developmental stage, a chaff curtain was placed approximately 20 kilometers ahead of the inflow border of the storm. Photographs of the intensity-contoured Cimarron Doppler radar scope showed positions of the chaff and the location of the suspected mesoscale circulation shaped like a hook. Other photographs showed a combination of vertical cyclonic shear and strong cyclonic inflow. At this point, the chaff appeared to be rapidly entraining into the mesoscale circulation.

While dual Doppler data were being collected within both the chaff and 10-centimeter precipitation return, the airplane collected dense horizontal wind and thermodynamic data in the south, southwest, and west flanks of the immediate environment of the storm.

Dr. McCarthy has obtained what appears to be a unique series of data on the action of a tornado cyclone. The data, when fully analyzed, will advance the understanding of the structure of the tornado cyclone and illustrate more clearly its interaction with the larger scales of motion.

EARTH SCIENCES

Present at the Beginning

A major geochemical discovery in fiscal year 1974 was the recognition that some of the matter present in the ancient solar system before the planets formed 4-1/2 billion years ago has been trapped and preserved in an unusual group of meteorites. This discovery provides a direct look at what was actually happening in our part of the universe when the Sun was just beginning to burn and before the Earth and Moon had formed.

Robert N. Clayton, Lawrence Grossman, and Toshiko K. Mayeda of the University of Chicago came to this conclusion by analyzing the isotopic composition of the element oxygen in an unusual group of meteorites called carbonaceous chondrites—so called because they contain much more carbon than do other meteorites. Some of the oxygen, they found, was so abnormal in its isotopic ratios that it must have been produced by nuclear reactions in the Sun or in another star before the meteorites themselves solidified.

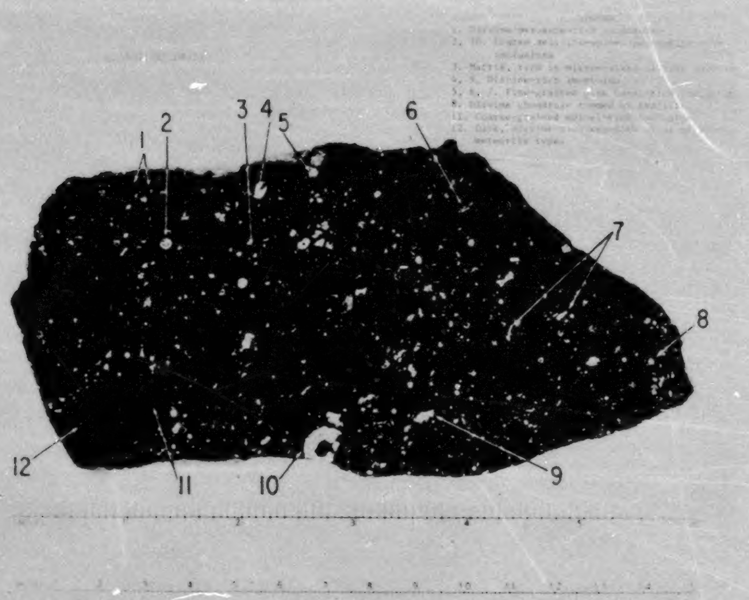
Oxygen, which forms about 50 percent by weight of both terrestrial rocks and meteorites, occurs as three different types of atoms, or isotopes, whose atomic weights are 16, 17, and 18. The relative amounts of these different atoms in such materials as rocks, meteorites, and ocean water are nearly the same, and all natural processes like melting, evaporation, and condensation produce only small variations (only 1 to 2 percent) in the ratios of one isotope to another.

However, material from the meteorites studied by Dr. Clayton and his colleagues contains much more of the oxygen-16 isotope than do any other meteorites or terrestrial rocks. This enrichment is far too great to explain by normal chemical processes, and the scientists concluded that it results from the mixing in of pure oxygen-16 formed directly by nuclear reactions going on either in the Sun itself or in another star.

This result agrees with other information about the meteorites themselves. The carbonaceous chondrites are believed to be some of the first solid matter to have formed when the Sun and the planets developed from a huge whirling cloud of hot gas and tiny dust grains about 4-1/2 billion years ago. Recently this view was confirmed by the discovery of small fragments of high-temperature minerals in a carbonaceous chondrite that fell near the village of Allende in northern Mexico in 1969. These small fragments are composed of minerals that would be the first to form as the gas cloud cooled down, and it is significant that the unusual excess of oxygen-16 seems to be concentrated in these high-temperature fragments and not in the other parts of the meteorite.

These studies, which were supported by NSF's Geochemistry Program, suggest that these inclusions formed so early in the history of the solar system that they trapped excess oxygen-16 that had been formed by nuclear reactions just beginning to operate in the Sun. This extra oxygen-16 was trapped before it could be mixed throughout the rest of the dust cloud. Other meteorites and the planets formed later, after the oxygen-16 had been well mixed, and they do not show any unusual composition. The material that makes up the rest of the Allende meteorite probably formed at this later time as well, and the early high-temperature minerals (with excess oxygen-16) were mixed with later low-temperature material (with normal oxygen composition) to form a single body that lasted for 4-1/2 billion years before falling to Earth in 1969.

This discovery shows that there are still exciting new possibilities in



This unusual meteorite that fell near the village of Allende in northern Mexico in 1969 contains small fragments of oxygen-16 enriched minerals. Scientists believe these minerals were present in the ancient solar system before planets were formed 4-1/2 billion years ago and were trapped in certain meteorites such as that of Allende. [Photo by Robert Clayton]

the active field of meteorite research. Dr. Clayton and his colleagues feel that important information about the early (pre-planet) history of the solar system may still be hidden in Allende and similar meteorites. After several years of studying meteorites in order to understand how the planets formed, scientists have suddenly discovered that they may be able to push their view even further back in time. These meteorites may now give us direct information about how both the Sun and the tiny bits of matter that would become meteorites condensed out of a primordial cloud 4-1/2 billion years ago.

OCEANOGRAPHY

Sea Turtle Migrations

Migrations of the green sea turtle, *Chelonia mydas*, have long mystified scientists. How is this large turtle able to migrate up to 2,500 kilometers and still return to within a kilometer of its previous nesting beach? Archie Carr of the University of Florida has accumulated 20 years of data concerning turtle migrations in his efforts to answer such questions. Dr. Carr interpreted his data as demonstrating a true navigational sense, although investigations of the acuity of turtle senses failed to produce conclusive evidence for a celestial, magnetic, or chemical-receptive basis for this assumed long-range piloting ability.

Recently, Joseph Richard of the University of Miami utilized Dr. Carr's data on the return of tagged turtles and on surface currents in the Caribbean. From this analysis he developed an alternate hypothesis of passive drift transport of green turtles from feeding grounds off the Nicaraguan coast to the major nesting beach at Tortuguero, Costa Rica. Dr. Richard's computer-generated plots of surface currents have successfully demonstrated that by passively drifting in surface currents, turtles would duplicate the seasonal migrations documented by 90 percent of tag returns from the Caribbean turtles.

Dr. Richard believes that the migration pattern is maintained because: (1) green turtles feed directly upstream from the nesting beaches; (2) strong southerly currents come close to the coast near the nesting beaches; and (3) the current is apparently strongest at the beginning of the nesting season. High mountain peaks behind the nesting beach may also be a visual cue assisting recognition of the beach used previously for nesting.

But the passive drift hypothesis becomes less tenable when considering the assumed migration of sea turtles from feeding grounds off the coast of Brazil to nesting beaches on Ascension Island in the mid-Atlantic. In this instance, Dr. Carr proposes that surface currents flowing from Ascension Island to Brazil may transmit a unique chemical cue that guides the turtles in their eastward swim.

Both the olfactory and passive drift interpretations of turtle migrations are based on circumstantial evidence. What is needed to conclusively test these hypotheses is observation of the turtle migrations and subsequent correlation of the movements with other environmental data. To date, balloons, floats, and fixed radio transmitters have failed as mechanisms for long-range tracking. Future research by both these investigators may be focused on exact documentation of turtle movements, perhaps using satellite tracking.

A giant green turtle rests on its nesting beach on Ascension Island, a small dot in the Pacific Ocean to which these turtles swim from their feeding grounds on the coast of Brazil, some 2,500 kilometers away. [Photo by Archie Carr]

Tritium—A New Ocean Tracer

Testing of nuclear weapons in the atmosphere releases a host of radioactive isotopes, which enter the ocean where they can serve as tracers of oceanic processes. One of these is the radioactive hydrogen isotope tritium (half-life of 12 years) in the form of tritiated water, HTO. Since the pre-bomb tritium levels in the ocean were almost undetectable, measurable tritium concentrations found in ocean waters today indicate that the water has been in contact with radioactivated atmosphere sometime during the past 10 to 20 years. This provides a tracer useful for oceanographic research. Beginning in 1969, a program carried out by Gote Ostlund and Claes Rooth of the University of Miami has used bomb tritium to test dynamic models of the thermocline—the zone of large temperature change separating warmer surface waters from colder deep waters.

Two general models have been used to explain the origin of the thermocline. In one model downward diffusion of heat from the ocean surface is balanced by the upward movements of cold bottom waters, which originate in subpolar seas. The second model postulates that distinct water masses form in specific parts of the ocean surface. Below the surface, these water masses retain their identify as they flow nearly horizontally for thousands of kilometers across ocean basins.

The University of Miami concentrated on the study of the Sargasso Sea area, south and southwest of Bermuda, and later on transects across the entire Atlantic Ocean. The project examined the annual wintertime formation of large volumes of relatively cool surface waters which spread south and southeast as a distinct water layer known as the Eighteen Degree Water. This tritium-tagged water formed a layer in the upper main thermocline, and its downward diffusion could be traced and studied. The decrease in tritium concentration in deeper waters to about one-sixth of its surface value gives an estimate of the effective vertical eddy diffusion, which is only 20 percent of that considered necessary for an oceanwide uniform diffusion thermocline model.

In short, the use of the manmade tracer tritium has shown that the rate of vertical exchange of water and dissolved matter in the central ocean basins is considerably less than previously thought. So horizontal movements of water masses may be the dominant processes forming the thermocline in the open ocean.

ENGINEERING

Engineering is science in the service of man. Engineering activities range from determining characteristics of Martian soil to the services of doctors, electricians, and those other technologists who make life possible in modern society. NSF supports "basic engineering science"—the development of technology from science and scientific principles that will be used in the solution of specific problems of society. Working primarily with universities through grants, NSF encourages the development of those promising engineering areas which are expected to "pay off" within 5 to 25 years. Unlike most other sciences, engineering looks not only to the forefront of science but also to industry to measure the success of supported work. Uniquely in engineering science, real success is measured in terms of solutions to real problems—the design of a better rapid transit, more effective communication systems, or more work output per kilowatt-hour. NSF's Engineering Division, which includes the traditional engineering science (but not materials), supports a broad range of disciplinary and interdisciplinary fields. The division's goal is to keep the basic engineering sciences in the Nation strong so that the technology is available when societal needs are determined.

During fiscal year 1974 the Engineering Division reorganized to be more responsive to society and the Nation's long-range needs. Its programs include new interfaces between government, industry, and universities, with emphasis on areas of energy, food, minerals, and interdisciplinary areas-of-opportunity, and with special emphasis on:

- University-industry workshops—recognizing the intimate interaction between engineering and industrial and government activities.
- Organized research areas—identifying broad problems having a unique opportunity for high impact through intensive coordinated research.
- Encouragement of young university researchers to engage in research on current problems.

Problem areas of special interest are:

- Optical communications—determining, theoretically and experimentally, the techniques and methodology necessary to develop practical systems.
- Advanced automation—concentrating on pattern analysis and processing fundamental to all advanced automation.
- Process dynamics—applying and using computer-aided control and optimization to upgrade the efficiency of chemical, petrochemical, and related industrial chemical production.
- Process synthesis—developing information and data that can lead to new processes and techniques saving energy, money, and critical materials.
- Food energy—increasing protein and food nutrients from normally non-edible sources by combining the skills of chemical engineers, bioengineers, and chemists.
- Wind engineering—providing greater understanding of the interaction between wind structures and urban areas.
- Planning and design of tall buildings—identifying and initiating new areas of research, and incorporating the best available information for planning and designing of tall buildings in the urban environment.
- Machine design technology transfer—bridging the gap between basic research results and their use in practice.

Of the funds available to universities for engineering research, 15 percent is furnished by the NSF while the majority of university support in this field is provided by Federal mission-oriented agencies. Within its limited sphere, however, the Foundation supports research with promise of future benefit to society. Examples include theoretical studies currently under way on the allocation of the overcrowded frequency spectrum which may have a profound effect on the communications industry; work on knit fabrics to reduce snag potential that may save Americans billions of dollars over the next decade; and work supported in mineral technology that is expected to significantly improve the raw materials picture at the foundation of the Nation's industrial enterprise. Activities of this nature, supported by NSF, take on added importance as economic pressures force industry to curtail industrial science and engineering development work.

Lowering the Cost of Steel Structures

The design of steel buildings and bridges, as conventionally practiced, makes the ultra-cautious assumption that each structural member has a yield strength equal to that of the weakest specimen recorded in mill tests (i.e., the "guaranteed minimum yield strength"). In reality, however, almost all steel members significantly exceed this minimum strength level—by 33 percent on the average—and members can be found with twice their assumed yield strength. Obviously, then, many kinds of structures are "over designed" for their specified use.

In an attempt to reduce the inefficiency of this process, Ralph L. Barnett of the Illinois Institute of Technology (IIT) has developed a new design philosophy in which the engineer does not necessarily have to choose the lowest possible value for every member. In effect, it turns the statistical variation in actual strengths into an asset by focusing attention on the strong members in a statistical population rather than on the weakest ones. Of course, the strong members would have to be identified by nondestructive proof-testing, and that would require that every member manufactured be tested and labeled with its actual strength level. But is should be noted that for several years the lumber industry has been proof-testing some species of its product on a piece-by-piece basis.

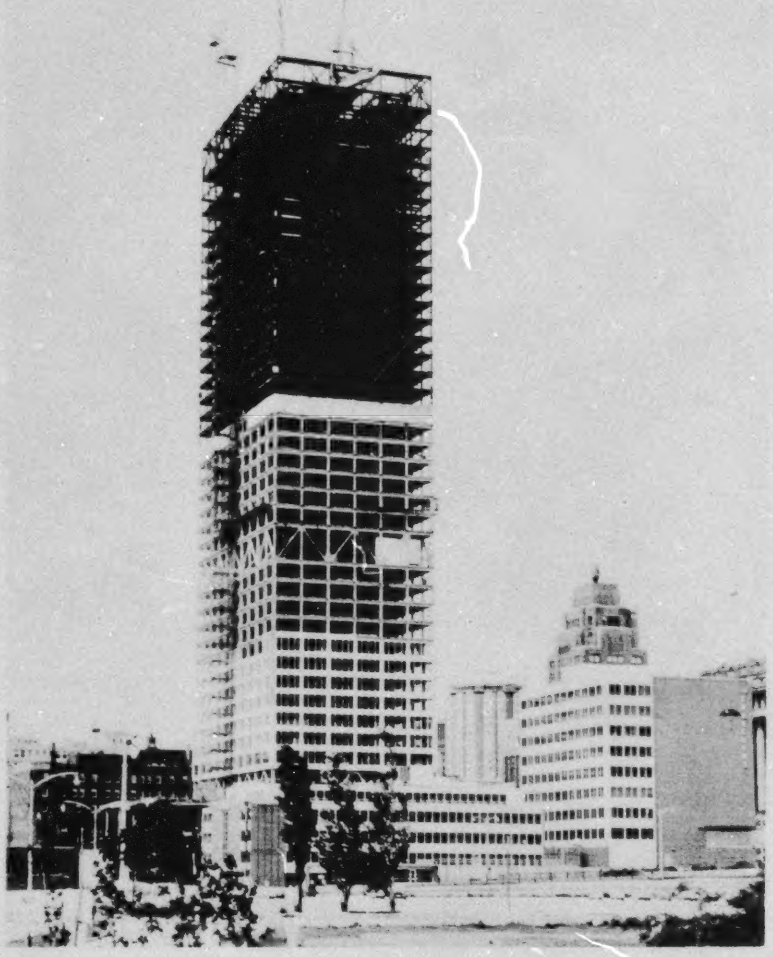
Dr. Barnett's work shows that new structural designs based on the exact strength of every proof-tested member would result in a 25-percent weight savings in the steel needed. In actual practice, however, a one-to-one match between loads and resistances is not possible, so the approach in each specific design situation is to convert the procedure to an optimization problem. Fortunately, this can be formulated as a linear programming problem with all its associated solution techniques.

As part of the research at IIT a comprehensive design-manufacturing-inventory system was developed and applied to various design problems. The engineers studied a simple two-bar truss to establish the effect of inventory size on potential cost savings. The savings in steel costs were found to be a constant 15.5 percent as the inventory increased beyond 25 members. The design of a 24-story apartment building using the nondestructive proof-testing philosophy showed that a 19.5-percent steel cost saving could be achieved.

Because various combinations of strength and size may be equivalent from a performance standpoint, the proof-testing procedure does not specify a unique geometry. This nonuniqueness enables designers to simplify the problems of joining structural members and to improve esthetics without compromising integrity or efficiency. An additional benefit of the proof-testing design system is structures that are lighter and more reliable.

One of the important characteristics of the new design procedure is that the more closely one can match the loads with the resistance, the greater the cost savings. That means cost efficiency is linked to the degree of specificity of user needs. Consequently, it follows that the proof-testing philosophy would favor domestic steel and metal suppliers who have the most definitive marketing information.

In its current state of development, such a methodology is far from being readily adoptable. Indeed, more explicit formulation of design spaces, including aspects of column and beam-column action, will have to be included. However, it is noteworthy that the general trend in structural engineering over the past decade has been to adopt a design philosophy based on "limit-state" concepts. This approach avoids complete dependence on unit or allowable stress criteria and enables engineers to design in a more performance-oriented mode by admitting such criteria as deformation or drift, buckling resistance, and post-buckling strength. The mathematical nature of Dr. Barnett's proposed methodology and limit-state concepts seem to hold strong promise for fruitful interaction.



Traditional steel structure designs are gradually being refined as construction engineers focus on new designs based on exact strength proof-tested steel members, resulting in possible 25-percent weight savings in steel. [Photo by U.S. Steel]

New Theory for Broadcasting

The mathematical theory of communications has been concerned almost exclusively with the reliable transmission of information from a single transmitter over a single channel to a single receiver, the kind of situation commonly found in the switched telephone network. The basic concepts for these analyses were described by Claude Shannon in his classic papers in 1948. Although David Sarnoff in the 1920's provided the framework for modern broadcasting systems, no similar mathematical theory exists for such systems. The proliferation of radio, television, urban mobile, satellite, and telecommunication broadcasting channels has resulted in a very crowded frequency spectrum without any real understanding of the fundamentals of the nature of broadcasting.

Recently, Thomas Cover at Stanford University formulated the problem of simultaneous communication of a single transmitter to several receivers via a single broadcast channel—situations such as a TV transmitter communicating with numerous individual stations, a satellite communicating with several distinct ground stations, or a lecturer speaking to many people with different backgrounds. Early results indicate that optimum allocation of the frequency spectrum will result through a rigorous theoretical treatment of broadcast channels.

Dr. Cover's formulation, in turn, suggested that of transmitting from a single source to many receivers using a simple connecting network of channels rather than using a single broadcast channel. The transmitter would then generate separate but related streams into each of the separate channels destined for one or more of the receivers. When communicating over such a simple network, each receiver might desire a separate "piece" of the source data suitable to his own needs, such as only the weather conditions for his own town. In addition, each receiver may have its own fidelity constraints, such as highly reliable communication at a minimum cost for the network. An example of such communications is the transmission of data from a source such as a telephone or cable television station to several receivers (several computers or several subscribers) via a simple network. The underlying idea is to optimize the total usage of all the channels rather than deal with each receiver separately.

More recently, Dr. Cover has obtained a very important result in what he calls "cooperative broadcasting" involving several transmitters. It has been shown that present procedures of allocating different frequency bands to different transmitters is not nearly as efficient as allowing each station with its own power to utilize the entire bandwidth with suitable switching. A method has been devised that depends on pooling the time, bandwidth, and power allocations of the individual transmitters. The current implementation scheme involves subtraction from the received signal of the estimated signals sent by the other transmitters, followed by decoding of the intended signal in an iterative manner. This particular result is expected to have a profound effect on the simplification of broadcast procedures and the allocation of the frequency spectrum for future communication systems.

Energy Conservation in Distillation

Distillation, the separation of mixtures of volatile components by thermal energy, is the most important separation method in the process industries. Forty percent of the capital investment in a petroleum refinery is in distillation systems. Although this technique dates back to the earliest days of multistage processing operations, many aspects of its practical implementation are still empirical, particularly with respect to efficient energy utilization. Lacking reliable thermodynamic data, such as vapor liquid equilibria, heats of vaporization, and free energy of solutions, systems designers have had to incorporate safety factors that result in inefficient energy use. Many industrial and academic groups are currently engaged in case-by-case, laborious, and often repetitive experimental data acquisition and evaluation activities, but increasing numbers of commercially important organic compounds have made it impossible to keep design data up with the demand. Hence, the development of a rational procedure for accurately predicting the relevant physical and thermal properties of these compounds is urgently needed.

Several years ago, K. C. Chao and R. A. Greenkorn of Purdue University initiated a program to develop a comprehensive method for generating the needed thermodynamic data, based on the property value attributable to each of the constituent radical groups in an organic compound. Using reliable data on a relatively small number of simple compounds, values contributed by the various groups can be calculated. Then the properties of more complex compounds can be synthesized and predicted without experimentation. Since the key to the accuracy and, hence, success of this method is the mutual interactions among groups, the procedure must involve more than a simple additive operation. As the molecular weight of a compound increases, the complexity multiplies, and the interactive contribution to the property values plays an increasingly important role.

To date the interactive properties of such basic organic structural units as methyl (CH_3), methylene (CH_2), methine (CH), quaternary carbon (C), hydroxyl (OH), and carbonyl (CO) groups have been determined in the form of partition functions. From such properties the relevant thermal and physical properties of solutions of alkane*/alkanol,** alkanol/alkanol, alkane/alkanone,*** and alkanone/alkanone have been calculated and verified. This research is being continued under NSF support with a view toward simplifying the mathematical representation and obtaining general results applicable to large classes of liquids of polar molecules and their solutions.

Examples:

* Alkane: 2.2.4 - trimethylpentane $(CH_3)_2CH\ CH_2\ C(CH_3)_3$

** Alkanol: n-octanol $CH_3(CH_2)_7OH$

*** Alkanone: 2-pentanone $CH_3CH_2CH_2COCH_3$

SOCIAL SCIENCES

Although the study of mankind can be pursued from many perspectives and by many methods, research supported by the Division of Social Sciences is characterized by an emphasis on increasing scientific knowledge about human beings and their interactions with one another, with their physical and biological environment, and with the social and cultural institutions man himself has created in great variety. To be scientific, studies must obtain objective, reliable, and verifiable findings, quantified where possible. They should be able to be replicated, to have predictive qualities, and to have an ability to be generalized. This special emphasis on strengthening the scientific base of social science is an integral aspect of the Foundation's responsibility.

Funds for research supported by the Division of Social Sciences remained at approximately the same level in fiscal year 1974 as in the preceding year, and the scope of the programs coverage was also substantially unchanged. Included in the division's activities are physical and cultural anthropology, including archaeology; economics; social and economic geography; sociology; social psychology; political science; social indicators; history and philosophy of science; science policy; and law and social sciences. A notable organizational change during the year was the unification of activities in support of linguistics research. These had previously been distributed among five separate programs depending on the primary focus of the work. Now it is organized as a coherent activity under the Special Projects Program. This development will enable closer monitoring and greater responsiveness to the needs of this active research area.

A number of interesting and important projects were supported, and a number of results became available, some of which are described here. An important feature of the Foundation's efforts is the attempt to provide for continuity of support, since fundamental work rarely has a rapid payoff and since contributions to theoretical and methodological problems may not only require long years of work but may be recognized only after still longer periods of time and often in unexpected circumstances.

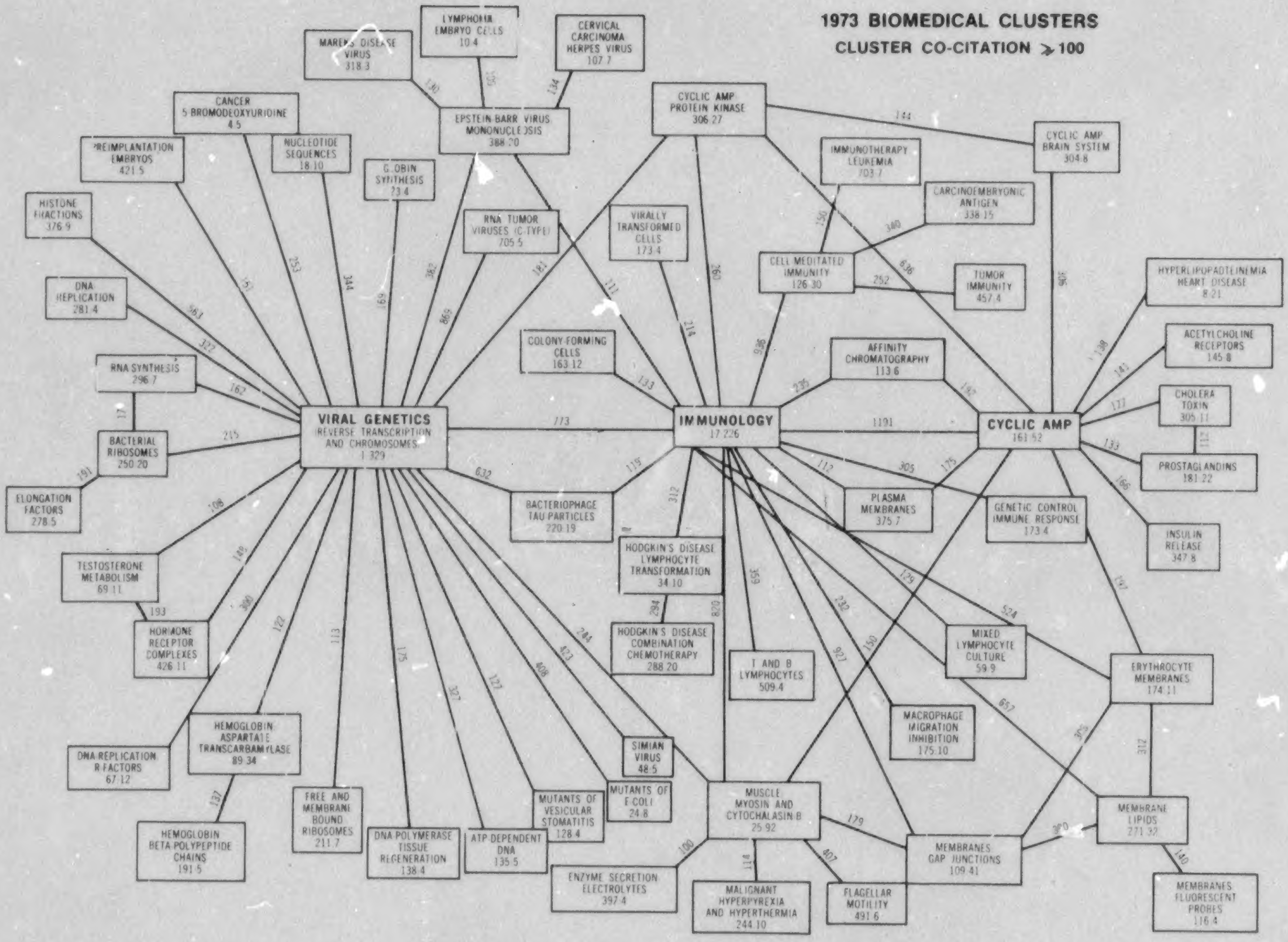
In addition to this aim of providing a stable base for established research, the division has continued its program of doctoral dissertation research support, which provides opportunities for more advanced scientific work to be done by young students just undertaking their thesis research. This program has been very successful, and a number of these have resulted in important contributions to the disciplines. A gratifying number of recipients of dissertation awards have gone on to research careers and have succeeded in the rigorous postdoctoral research competition.

The Changing Disciplinary Structure of Science

The study of the development of scientific groups and new areas of scientific development has proceeded quite rapidly in the past several years. In particular, several new techniques using co-citation measures and multidimensional scaling as techniques for clustering citation data have made it possible to define areas of high activity within the scientific literature and to list all the scientists and published works that constitute the core of a scientific area. This research, done by Henry Small of the Institute for Scientific Information in Philadelphia, promises to provide an important tool for the National Science Foundation and other funding organizations for locating and supporting shifts in scientific activity and to stimulate activity in areas that are important to their specific agency goals.

What Dr. Small and his colleagues have done is to develop a computerized system that permits clustering of an annual cumulation of the *Science Citation Index* to determine the structure of science in a particular year. Structure is defined as the sum total of linkages among papers co-cited (pairs of papers cited together) above a certain minimum threshold. Clusters of highly co-cited pairs are derived automatically, and each cluster corresponds to a traditional or perhaps newly identified scientific specialty. These specialties are usually more highly specific in subject matter (for example, reverse transcription of nonlinear optics) and compact in structure than traditional disciplines (physics, genetics). By drawing lines connecting the cited papers, researchers can graphically represent the clusters on a diagram, as well as the strength of linkage between papers. The various clusters can be manipulated by varying the parameters for indicating linkage. A higher linkage threshold will cause a cluster to become more compact and a lower one will increase the size of a cluster. Applying this technique it has been found that larger specialties break down to a finer structure and subgroups appear which focus around key papers or individuals who are leaders in particular specialties. These manipulations result in identification of basic units which, when clustered, identify the broad discipline.

Also, these clusters may be viewed as dynamic systems which change from year to year. It has been found that the individual clusters and groups of clusters are subject to


1973 BIOMEDICAL CLUSTERS
CLUSTER CO-CITATION ≥100
MAREKS DISEASE VIRUS 318 3
LYMPHOMA EMBRYO CELLS 10 4
CERVICAL CARCINOMA HERPES VIRUS 107 7
CANCER 5 BROMODEOXYURIDINE 4 5
EPSTEIN BARR VIRUS MONONUCLEOSIS 388 20
PREIMPLANTATION EMBRYOS 421 5
NUCLEOTIDE SEQUENCES 18 10
GLOBIN SYNTHESIS 23 4
HISTONE FRACTIONS 376 9
RNA TUMOR VIRUSES (C-TYPE) 705 5
DNA REPLICATION 281 4
COLONY-FORMING CELLS 163 12
RNA SYNTHESIS 296 7
VIRAL GENETICS (REVERSE TRANSCRIPTION AND CHROMOSOMES) 1 329
BACTERIAL RIBOSOMES 250 20
ELONGATION FACTORS 278 5
BACTERIOPHAGE TAU PARTICLES 220 19
TESTOSTERONE METABOLISM 69 11
HORMONE RECEPTOR COMPLEXES 426 11
DNA REPLICATION R FACTORS 67 12
HEMOGLOBIN ASPARTATE TRANSCARBAMYLASE 89 34
HEMOGLOBIN BETA POLYPEPTIDE CHAINS 191 5
FREE AND MEMBRANE BOUND RIBOSOMES 211 7
DNA POLYMERASE TISSUE REGENERATION 138 4
ATP DEPENDENT DNA 135 5
MUTANTS OF VESICULAR STOMATITIS 128 4
MUTANTS OF E COLI 24 8
SIMIAN VIRUS 48 5
CYCLIC AMP PROTEIN KINASE 306 27
CYCLIC AMP BRAIN SYSTEM 304 8
IMMUNOTHERAPY LEUKEMIA 703 7
CARCINOEMBRYONIC ANTIGEN 338 15
VIRALLY TRANSFORMED CELLS 173 4
CELL MEDITATED IMMUNITY 126 30
TUMOR IMMUNITY 457 4
HYPERLIPOPROTEINEMIA HEART DISEASE 8 21
AFFINITY CHROMATOGRAPHY 113 6
ACETYLCHOLINE RECEPTORS 145 8
CHOLERA TOXIN 305 11
IMMUNOLOGY 17 226
CYCLIC AMP 161 52
PROSTAGLANDINS 181 22
PLASMA MEMBRANES 375 7
GENETIC CONTROL IMMUNE RESPONSE 173 4
INSULIN RELEASE 347 8
HODGKIN'S DISEASE LYMPHOCYTE TRANSFORMATION 34 10
HODGKIN'S DISEASE COMBINATION CHEMOTHERAPY 288 20
T AND B LYMPHOCYTES 509 4
MIXED LYMPHOCYTE CULTURE 59 9
MACROPHAGE MIGRATION INHIBITION 175 10
ERYTHROCYTE MEMBRANES 174 11
MUSCLE MYOSIN AND CYTOCHALASIN B 25 92
MEMBRANE LIPIDS 271 32
MEMBRANES GAP JUNCTIONS 109 41
ENZYME SECRETION ELECTROLYTES 397 4
MALIGNANT HYPERPYREXIA AND HYPERTHERMIA 244 10
FLAGELLAR MOTILITY 491 6
MEMBRANES FLUORESCENT PROBES 116 4
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927
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100
114
407

A new technique identifying the structure of scientific research based on published papers gives an idea of how scientific studies are grouped together in certain years and then how these groups change in succeeding years. With a computerized system that permits clustering of co-cited publications from an annual cumulation, researchers at the Institute for Scientific Information can categorize scientific specialities. By drawing lines between the cited papers, they can graphically represent the clusters on a diagram as well as the strength of linkage between papers. The linkages in the 1973 biomedical clusters, for instance, show intense activity in viral genetics and immunology.

dramatic change. When the linkage thresholds are raised or lowered, the science cluster diagram begins to take on an appearance of a rapidly changing landscape. Depending on the nature of the change in threshold, new specialties may emerge in fast moving fields in as little time as 3 to 6 months, and drastic internal shifts can be observed in existing specialties. These shifting diagrams may be exceedingly useful in the determination of science policy and planning the allocation of resources for the future.

The Economics of Slavery

The traditional interpretation of the economics of slavery in America has been challenged in a recent book, *Time on the Cross*, written by Robert Fogel and Stanley Engerman of the Universities of Chicago and Rochester. The massive quantitative evidence which they compiled and analyzed with the aid of econometric methods calls into question the once widely accepted notion that slavery, as practiced in the American South, was an inefficient production system and that it was very harmful, if not ruinous, to the southern economy. It is the authors' contention that traditional figures showing southern income far below northern income are misleading because of the extremely high levels attained in a few Northeastern States. Southern per capita income in the decades before the Civil War, they find, actually exceeded that of the North Central States and was higher than any European country but England. Moreover, it was growing appreciably faster than in the North.

The complex productivity index developed by Drs. Fogel and Engerman indicates that southern slave farms were 28 percent more efficient than southern free farms, and 40 percent more efficient than northern family farms. To some extent this startling result is accounted for by the economies of scale realized on large slave plantations, but in the main, according to their analysis, it was due to the high quality and efficiency of black labor and the special skills of black managers. Citing reliable census data, they report that, "On a majority of the large plantations, the top non-ownership management was black." Plantation records and slave market invoices also are cited to prove that less than 2 percent of slave families were broken up by owners and that most slaves sold were either unmarried or were sold with their mates. While this sort of evidence in no way condones slavery or establishes it as a progressive social institution, it does shed light on the degree to which owners perceived their self-interest to be associated with a stable productive work force.

Unlike most of the densely quantitative works of the new economic history, the Fogel-Engerman book has been widely discussed in the popular press in addition to the usual professional journals. Both the praise and the criticism it has received make it plain that it is not the last word on the subject but rather the opening round of what promises to be an increasingly scientific and very useful historical inquiry. The authors themselves regard their study not as a complete history but as a correction to impressionistic and partial narratives. In particular, they emphasize that their statistical inferences about average economic well-being on the plantations do not speak to moral issues or to the general psychological injuriousness of the slave system which must be approached largely by nonquantitative means. At the same time their research testifies to the efficacy of mathematical techniques for probing a wide variety of important historical questions.

"Hard" Measurement of "Soft" Variables

Precision in scientific results is directly related to the ability to make precise distinctions in measurement; the lack of precise measurement has often been a particular problem in the social sciences. Because of the nature of the phenomena to be measured, the more highly developed scaling procedures of physical measurement have provided very little guidance. An interdisciplinary team including two political scientists, a psychologist, and a psychophysicist at the State University of New York at Stony Brook is currently engaged in a program of research that promises to make very substantial progress toward the goal of improved measurement.

In a series of experiments, the researchers have been building social scales using the procedures of psychophysics. One of the chief problems in psychophysics is the discrepancy between changes of physical stimuli such as the change in the intensity of light and the human perception of the change. Two procedures are used to establish the relationship between the change in the physical stimuli and human perception. The individual is asked to make an estimate of the magnitude of the intensity of the physical stimulus relative to a standard. The estimate is made in several ways (or modes); it may involve the individual assigning a number, turning sound up the same amount that the light has increased in intensity, and squeezing a hand grip. The multiple-mode estimates permit the second procedure used by psychophysicists, which is cross modal validation. There are known functional relationships between the different modes. If these known relationships hold in making estimates of the intensity of the stimulus, this is treated as validating the estimates that are made by the individual.

Exactly the same procedure is being used by the research team at Stony Brook except that they substitute a social stimulus for the physical stimulus. These social stimuli may be individual words, phrases, or sentences; or they may be visual stimuli such as pictures. The numerical estimates assigned by the individuals can then be used as the basis for assigning values in further research using the stimuli. The cross modal validation procedures permit a very precise check on the validation of the assignment of these values.

By various procedures, researchers have been able to build and validate scales measuring the importance of different political offices, the importance of different forms of political participation, and feelings toward political institutions. In their most recent set of experiments they have been using adjectives as the stimuli to be responded to by the subjects in the experiment. The subjects were presented with an adjective or adjectival phrase such as "adequate," "not too good," or "not too bad" as the standard stimulus. Then the subjects were presented a series of adjectives and asked to estimate their relationship to the standard adjective. Across four separate experiments with separate sets of subjects, different objects to which the adjectives were being applied, and different combinations of adjectives, the experimenters have found a very remarkable stability in the values being assigned to adjectives. "absolutely perfect" was used in two of the experiments; in one the ratio of the values assigned for "absolutely perfect" to the standard was 6.9 and in the other it was 7.0. "Good" was used in each of the experiments and the ratios of the values assigned for "good" to those of the standard were 2.2, 2.0, 2.4, and 2.1. The adjective "very" was used to modify "good" and "bad" in two of the experiments. In each case the modifier "very" increased the ratio of the values to the standard by exactly the same amount. The cross modal procedures indicated very strong validity for the experimental results.

These procedures hold the potential for a substantial improvement in social science measurement. They permit the assignment of a ratio scale to social stimuli. The validation procedures are rigorous and precise. The procedures can be used in a wide variety of research enterprises, for instance, to develop better questionnaires in survey research, or to measure very precisely the stimuli that are presented to subjects in experimental research. They can be used with content analysis procedures to attain sophisticated measurement of documentary data, or for measuring various aspects of visual stimuli presented in, for example, television. The initial work of this group is already being tested by other NSF grantees in quite different substantive areas to determine its applicability to their research. This research may well improve the precision of measurement in the social sciences by several orders of magnitude.

MATERIALS RESEARCH

The Foundation's Division of Materials Research is concerned with understanding the special properties—electrical, mechanical, chemical, magnetic—of solids. Improvements in this basic understanding lead, in time, to improved or totally new industrial products. During fiscal year 1974 the division was regrouped into three sections to allow the programs a better defined scope and help cope with the range of disciplines covered. The new organization consists of:

- Solid State Sciences—
  - Solid State Physics
  - Quantum Solids & Liquids
  - Solid State Chemistry
- Metallurgy and Materials—
  - Metallurgy
  - Ceramics
  - Polymers
- Materials Research Laboratories

The emergence of the Foundation's Energy-Related General Research (ERG) program (discussed in the introduction to this chapter) led to a close evaluation of NSF's materials research activities to identify existing energy-related research and other research areas that the division should try to emphasize. For example, NSF has substantial programs in mechanical properties, surfaces, and superconductivity, all of which are of importance to the ERG program. A look at emerging national programs revealed that the behavior of materials in the unique environment of coal gasification systems stands out as an important, but little understood, area. A workshop on "Materials Problems and Research Opportunities in Coal Conversion" was held at Ohio State University to better define basic research that would be of help to the long-term commitment in this area now developing in the United States.

The identification and definition of research opportunities and interaction with the research community in these areas is a broad and continuing process, and partial support to special topical meetings is a device being used by all the division's programs. The engineering-related programs often support workshops with limited attendance, semi-structured discussion, and roughly equal participation by academic and industrial personnel. Workshop reports are published and distributed.

Another device for grouping research of this sort is "coherence areas"—groups of grants with a common theme. Currently, the

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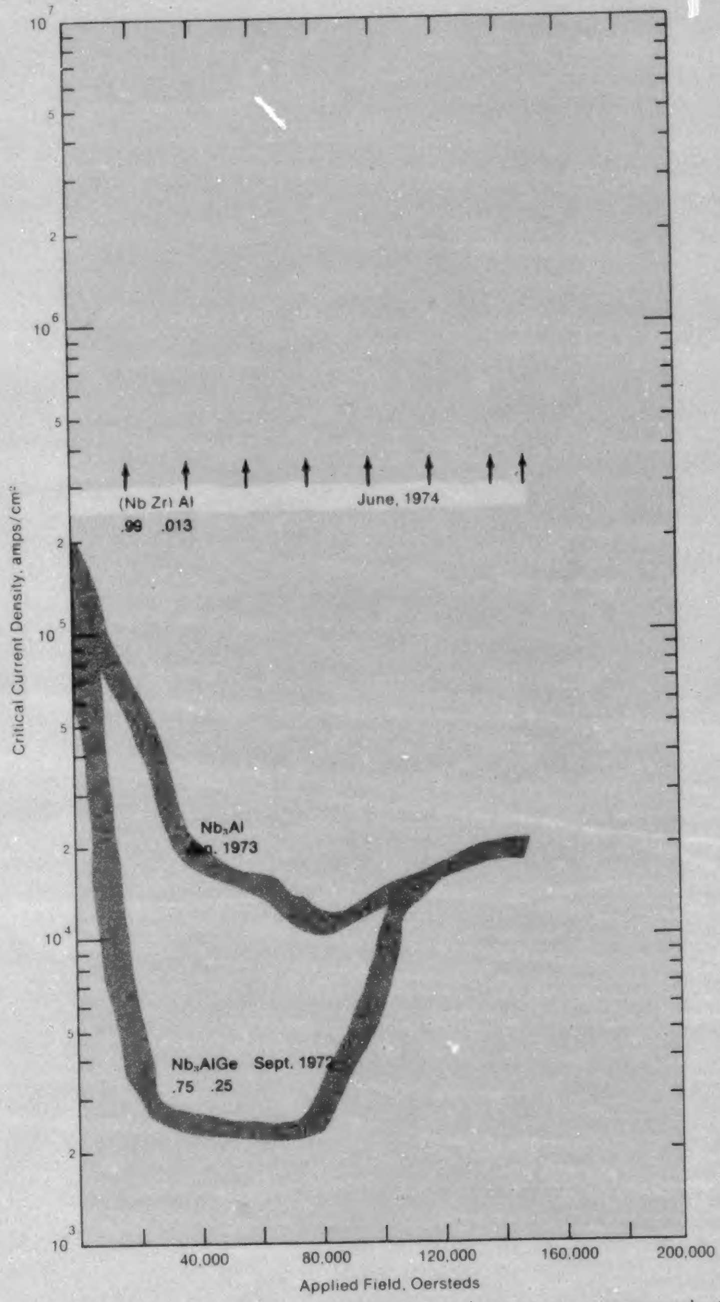
division is maintaining two of these—biomaterials and hard materials. Meetings are held once or twice a year to exchange and discuss the results, and to set goals. In biomaterials, this provides a device for coordination with other agencies, primarily the National Institutes of Health.

Fabrication Technology for a Practical Superconducting Material

Large equipment used by electric utilities in generation and transmission of electric power could benefit greatly if superconducting materials—those which conduct electricity with very low losses—could be used extensively. Unfortunately, most superconductors lose their desirable properties if the current they carry becomes too large, if the magnetic field in which they are used is too large, or if their temperature rises too high. Of the thousands of compounds known, the materials that best avoid these difficulties are compounds of niobium with aluminum, germanium, or silicon; a typical compound is Nb_3Al. However, these compounds are very brittle, and their superconducting properties are highly sensitive to chemical composition and crystalline perfection. Thus, production of wire from these materials which is strong enough and resilient enough to permit the winding of magnet coils has been very difficult.

However, by careful control of the chemical and metallurgical processing, Robert Rose at the Massachusetts Institute of Technology has developed a wire with greatly improved properties. Furthermore, the technique can be easily adapted to the present industrial processes used in production of niobium-titanium alloys, the most common commercial superconducting products now manufactured. In comparison to niobium-titanium, the alloys of



By careful control of the chemical and metallurgical processing, a superconducting wire has been developed at MIT with improved properties for conducting high amounts of currents over large magnetic fields. In this chart, the white area shows that the improved material, niobium zirconium aluminum (NbZrAl), can carry and maintain a current of about 300,000 amperes per square centimeter, at magnetic fields in excess of 150,000 oersteds. Wires of different compounds such as niobium aluminum (**NbAl**) and niobium aluminum germanium (**NbAlGe**) do not have these improved properties.

niobium with aluminum, germanium, or silicon can be used at temperatures at least twice as high and at electric currents at least three times as high.

A major problem in production of these newer materials has been elimination of voids that develop when the constituents, such as niobium and aluminum, react at high temperature to form the compound Nb_3Al. These voids increase the brittleness of the material and decrease its current carrying capacity. However, precise control of the geometry of the constitutent metals has permitted control of the void geometry and consequent reduction of their undesirable effects.

The procedure for producing these materials consists of four steps. First, a multifiber composite of bundles of aluminum and niobium wires is fabricated by swaging and drawing (a composite only 0.01 centimeter in diameter may contain 10,000 to 100,000 wires). Then a short heat treatment at 1,700° C. in a protective argon atmosphere permits the aluminum and niobium to chemically react. A final heat treatment around 750° C. causes additional internal changes which increase the usable temperature.

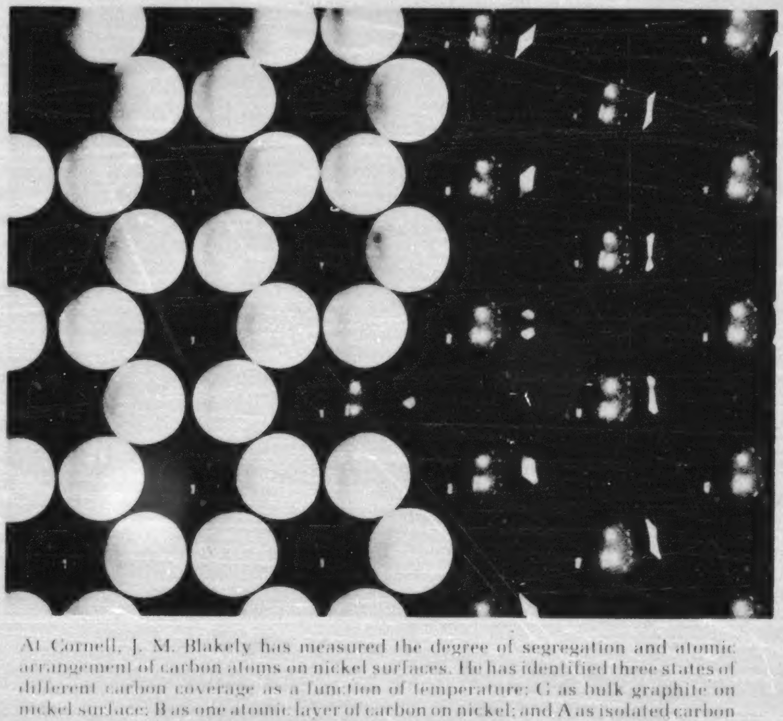
The improvement in properties that results from these heat treatments—determined by Dr. Rose in tests at the National Magnet Laboratory—permits the material to carry a current of about 300,000 amperes/cm^2, compared to about 10,000 amperes/cm^2 available earlier. Furthermore, this high level is maintained in applied magnetic fields in excess of 150,000 oersteds, performance which is superior to any commercially available superconductor. Still higher current densities appear possible. The materials developed in this study should be reasonable in cost and should permit development of large-scale equipment.

Binding of Carbon to Nickel Surfaces

Many, if not most, of the physical and chemical processes important to our everyday life occur at surfaces. For example, the properties of many important catalysts, substances that promote chemical reactions, are strongly dependent on the nature of their surfaces. Also, the embrittlement of structural materials is often caused by the migration of impurities to the interfaces between different crystallities (grain boundaries) in the bulk material. Despite the existence of a qualitative understanding of the influence of the surfaces, there are fundamental questions in surface science unanswered.

Using recently developed electron scattering techniques, J. M. Blakely of Cornell University has measured the degree of segregation and atomic arrangement of carbon atoms segregated on nickel surfaces. His studies show evidence of three distinct states of carbon coverage, called A, B, and G, with a remarkably sharp transition between phases A and B at 1,180° K. From a combined analysis of the composition and structure of the surface, he has determined that the A state is isolated carbon atoms on the nickel surface, B corresponds to formation of one atomic layer of carbon, and G represents bulk graphite on the nickel surface. In addition to these structural determinations, a thermodynamic analysis yields a value for the binding energy of carbon to the nickel surface which is less than 1 percent larger than that of carbon in graphite.

The information about the binding energy and coordination of the carbon on the nickel surface obtained in this investigation is directly relevant to the understanding of the



At Cornell, J. M. Blakely has measured the degree of segregation and atomic arrangement of carbon atoms on nickel surfaces. He has identified three states of different carbon coverage as a function of temperature: G as bulk graphite on nickel surface; B as one atomic layer of carbon on nickel; and A as isolated carbon atoms on nickel. A photograph of a ball model depicts, on the left-hand portion, the probable arrangement of one atomic layer of carbon. [Photo by J. M. Blakely] heterogeneous catalysis of hydrocarbon reactions. The effectiveness of the transition metal catalyst depends upon a delicate balance of the binding energies in an intermediate state including adsorbed carbons and in the initial and final states. The energy of the carbon-metal bond plays a significant role in determining this balance. Furthermore, the catalytic surface is sometimes coated with a carbon layer under actual operating conditions.

Intense Laser Modulation of Acoustoelectronic Interactions

The interaction of light with acoustic waves in certain semiconducting materials offers the possibility of rapidly scanning and detecting light patterns as well as detecting and modifying propagation of acoustic waves. These phenomena are of basic importance in potential devices for modern signal handling, pattern recognition, and nondestructive testing; moreover, they provide a fundamental probe for investigating the behavior of materials.

The generation, propagation, and control of acoustic waves in materials has been of major interest at the Purdue University Materials Research Laboratory from both the fundamental and the engineering points of view. One of the more basic aspects of this effort has involved the continuing study by Ralph Bray of the Physics Department of the properties of amplified phonon, or acoustic, beams in a semiconductor, gallium arsenide. In this material, pulses of high voltage are used to amplify phonons from the thermal equilibrium background by factors of the order of 10^{10}. These phonons travel through the sample with the velocity of sound in narrow domains on the order of 1 millimeter wide. The domains are regions of very high resistance which concentrate most of the voltage drop across the sample. Initially, before the domain can fully develop, a high current passes through the sample. After approximately 2 microseconds the domain is fully formed, and the current is reduced from its initial value by an order of magnitude.

Recently, in the course of light scattering studies of the amplified phonon beams using a powerful pulsed laser, it was discovered that the laser greatly modulates the current in the sample—but only when the laser light is directly incident on the propagating domain of acoustic flux. A factor of ten increase in the current can be achieved, whereas incidence of the light elsewhere on the sample produces a very small modulation of the current. The unusual light-induced modulation of the current is accounted for by the photoexcitation of trapped electrons into conducting states in the highly resistive domain.

The observation of the laser modulation of the domain current has two immediate useful applications. First, the domain, as it propagates across the sample, can scan the sample and provide a photoconductive time response pattern related to the spatial distribution of incident light. R. L. Gunshor and his colleagues in Purdue's Electrical Engineering Department plan to study possible uses of this phenomenon in the detection of light patterns. Conversely, moving the light spot along the sample provides a scan for the presence of the amplified acoustic flux and its propagation velocity. Thus, it is possible to probe in detail the fundamental properties of the acoustic domains and the underlying physical interactions that give rise to them.

Highly Efficient Catalysts for Making Polymers

Polymeric materials surpass all other manufactured materials in volume of production. They are fabricated into fibers, films, molded objects, coatings, and other objects, and represent a very significant factor in the national economy. Polymers are made by chemically connecting large numbers of small molecules, called monomers, by a process known as polymerization. This process received a very significant advancement some 25 years ago with the discovery of certain catalysts which promote polymerization into stereoregular polymers with superior properties. While these catalysts are used in much of commercial polymer production today, they have certain disadvantages. First, they are highly corrosive and must be subsequently removed from the polymer by energy-consuming extractions and solvent recovery. Second, they are not completely efficient, resulting in 3 to 5 percent low molecular weight polymer, a significant waste of scarce raw material.

Work sponsored by NSF at the University of Massachusetts has recently produced stereospecific catalysts which are essentially 100 percent efficient in polymerizing olefin monomers into polyolefins. In addition, these catalysts are noncorrosive and have the added advantage of decreasing the flammability of the resulting polymer. Because flammability of polymeric materials is now being recognized as a serious problem, the possibility of a highly efficient, noncorrosive catalyst that also increases the flame retardancy is highly promising.

COMPUTER RESEARCH

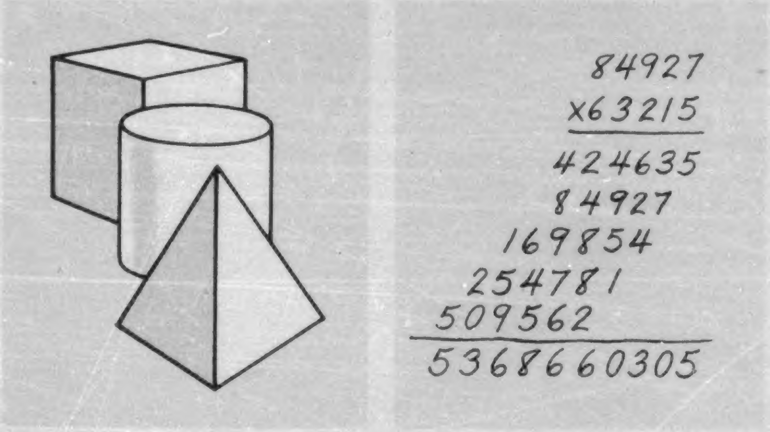
Changes in technology and knowledge and changes in their impact on the complexity of human organization have been a constant phenomenon throughout the history of man but have, until the past century, accelerated only gradually. Today, however, the rate of change is unparalleled in human experience. Stasis, it appears, has permanently yielded to flux. In furtherance of a belief that research is, at the same time, both an instrument and a symbol of progress, the Division of Computer Research (formerly the Office of Computing Activities) supported research in all areas of computing during this fiscal year.

The division places major emphasis on fundamental aspects of computer science and engineering and on research directed toward the development of techniques that increase the responsiveness of the computer to the requirements of scientific disciplines. Projects relative to privacy and computer system security, to the human-machine interface, and to energy-related research are also supported by a newly established Special Projects Program. In addition, a limited amount of support for travel to selected international conferences and meetings is provided.

Theory of Algorithms

Human beings have been seeing, hearing, comparing, calculating, making decisions and, in general, perceiving and thinking for thousands and thousands of years. During that time we have developed techniques and procedures for humans which are very good and possibly optimal. The advent of the computer, which can perform some of these same functions but which works very differently, has given us reason to reexamine many of these activities. We are discovering some interesting results. For example, humans can instantly recognize a picture showing a block standing behind a cylinder which stands behind a pyramid. Computers have a very hard time doing this. Clearly, this recognition problem is not "hard" in any absolute sense but its apparent difficulty depends upon the design recognition by the perceiver. Humans are better designed than computers for this task. On the other hand, multiplying two long numbers together is relatively hard for humans (impossible for most of us without some auxiliary devices such as pencil and paper), but relatively easy for computers because of a new procedure which is better suited to the design of computers. Interestingly, humans find this new procedure much more difficult than the old one and the old way may be optimal for us.

This search for new procedures is an important aspect of computer science and engineering research and one which is producing an immediate payoff in reducing computing time and cost. For example, very many problems in science, engineering, economics, and business involve solving systems of equations. The core of this process is the handling of matrices (i.e., arrays of numbers) which express the relationships among the equations and unknowns. Such matrices often have thousands of rows and thousands of columns (or millions of entries, in all). In most cases, all but 1 or 2 percent of the entries are zero. The traditional way of treating these matrices requires keeping a record of each entry, whether zero or not; i.e., a complete picture of the matrix, since we need to know both the value and the position of each entry. Magnetic tapes, magnetic discs, or other auxiliary memory devices can be used to provide the large memory capacity needed for this purpose, but simply reading and rewriting these millions of entries as often as is necessary to solve a typical problem



The search for new theories in computer science has produced results not only in new computer techniques but in reexamination of human versus computer procedures. For instance, human beings can instantly recognize a picture of a block standing behind a cylinder which stands behind a pyramid (left). But computers have a hard time doing this. On the other hand, humans have difficulties multiplying two long numbers, and most need auxiliary devices such as pencil and paper (right). Computers can do this work easily.

can require hundreds of hours, even at electronic speeds.

W. E. Rheinboldt and his colleagues and students at the University of Maryland have discovered a procedure for solving such equations which requires knowledge for only the non-zero entries. This procedure reduces computing time by 25 percent in the relatively simple case of linear equations and may produce an even greater advantage in the more complex nonlinear problems.

Computer Science Survey

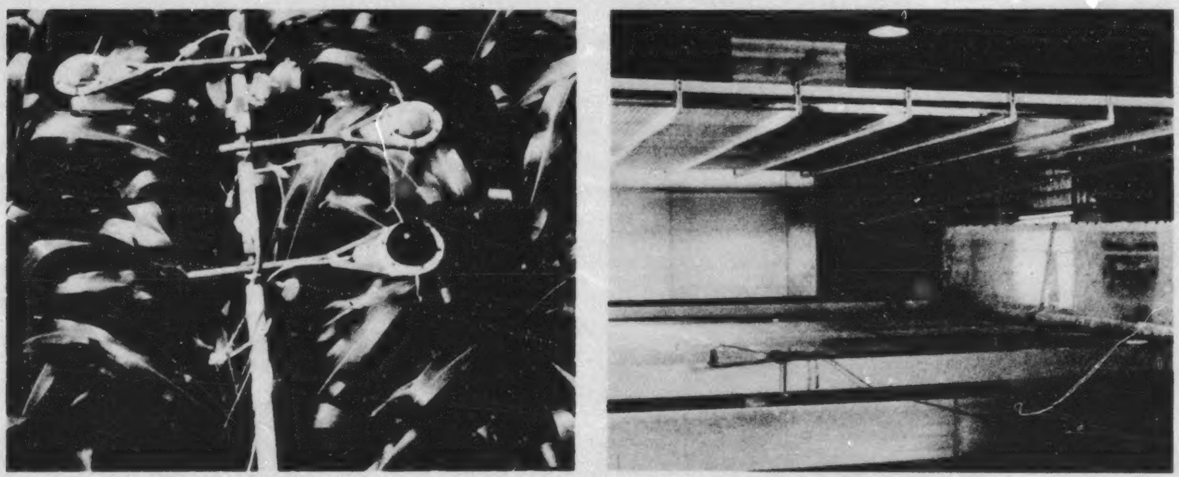
Computer Science and Engineering is a new and rapidly developing basic research discipline. Its explosive growth, both in terms of students and number of departments offering degrees, has paralleled the growth of computer usage in all parts of society. For the first time in its quarter century of activity, and with support from the Division of Computer Research, this discipline will be given a comprehensive examination by researchers in the field. This examination, which will conclude with the preparation of a major report, is expected to take nearly 3 years to complete. Bruce W. Arden, Chairman of Princeton's Electrical Engineering Department, will supervise the undertaking. The report will define what computer science and engineering is, describe major research problems now under investigation, and point out future educational and research opportunities. It will also seek to explore the relationship between research in computer science and the increasing use of computers to help solve pressing national problems.

Hierarchical Computing Systems

The increasing sophistication and quantification of research efforts have broadened the demand for scientific computing services. Some of these services, such as on-line high-speed data acquisition, complex pictorial display, and timely feedback of results to the investigator, have led to the exploration of new types of computing resources to augment the conventional computing center. One type of resource which has been successfully implemented at a number of institutions is the hierarchical computing system. This typically consists of a number of small computers in laboratories and offices, connected in one or more hierarchical layers to a central computer system.

An example is the Multidisciplinary Integrated Research Activities in Complex Laboratory Environments (MIRACLE) system at Purdue University. The system consists of a collection of minicomputers and microcomputers in laboratories and at field sites. These are connected via direct wires or telephone lines to a data concentrator, thence to a main processor, and finally, to the main university computer center. With this hierarchical arrangement, the really "heavy" computing is done centrally, and tasks requiring constant attention or fast response are done by the most appropriate small computer.

At the Purdue facilities, a multidisciplinary array of research projects includes investigations in biochemistry, physiology, structural engineering, meteorology, and environmental science. The multidis-



New types of computing resources such as the hierarchical system have provided aid for the increasing sophistication and quantification of research efforts. Studies of ecosystems at Purdue use minicomputers to reach into a cornfield (left) where solar radiation is recorded and into a laboratory (right) in which a simulated watershed is used in basic hydrology studies. Data from these laboratory computers are transmitted by a series of various devices to the main university computer center.

ciplinary environment greatly facilitates the transfer of techniques and ideas among research disciplines, and also helps get research results quickly into public use. For example, the Purdue group has developed a Generalized Environmental Model, using concepts resulting from research in meteorology, atmospheric science, soil science, and hydrology. This model, implemented on the MIRACLE central processor, accepts data in real time over telephone lines from remote field installations, where sensors monitor phenomena such as soil temperature and moisture, atmospheric gases and particles, and solar radiation. The system generates a variety of research outputs and also produces agricultural advisory information on flooding, irrigation, crop development, harvesting, fire probability, and pest management, and urban advisory information on energy demand, health episodes, airport safety, and roadway freezing.

Software Quality Research

Another thrust of the Division of Computer Research is directed at one of the biggest problems in the computer field: the need to improve the quality of computer programs. Errors in scientific programs are frequently subtle and may escape detection for months or years. They differ from errors in business computations, such as when a surprised recipient receives a check for $99,999.99 when no check was due. During the past 12 years there has been much research in numerical mathematics for performing basic computations required in science and engineering, including an analysis of errors introduced in long sequences of steps typical of scientific computations. This research is fundamental to providing science researchers with accurate, consistent, well-documented, and extensively tested computer programs. A major collaborative project to improve the quality of scientific computer programs is under way at nine universities and laboratories with support from NSF and the Atomic Energy Commission.

Privacy and Access Control

Concern continues to grow over the threats to privacy posed by computer data banks. This concern was expressed in the Presidential State of the Union Address delivered on January 30, 1974, and amplified further in a special radio address delivered by the President on February 23. In that talk, he announced the formation of a special Domestic Council Committee on Government Data Banks and Individual Privacy to be chaired by the Vice President. In addition, legislation is pending in both Houses of Congress, and many States are considering or have passed laws controlling the operation of computer-based personal data banks.

The attending legal, social, ethical, and technological considerations of computer privacy have been thoroughly sorted out in a series of studies and reports produced over the past several years. The main focus of Government interest has been on nontechnical matters. However, several relevant technical problems remain, some general and some specific to particular regulatory proposals. These problems involve primarily the development of adequate access control methods to assure confidentiality of data and measures of the information content of a data bank.

Several research projects on computer security ranging from pragmatic short-term data-gathering studies to highly mathematical and speculative basic research have been funded by the division. For instance, Donn Parker of the Stanford Research Institute is continuing his study of computer-based crimes with emphasis on how the computer system was compromised by the criminal. The data he collects will provide invaluable information for the design of new protection measures and for research into secure operating systems. Also, William Maxwell at Cornell University is studying techniques for making computer systems more secure through better software. He is looking at ways to control access to data in systems where several different users are sharing a simple computer with overlapping data sets. At the theoretical end of this spectrum of projects, Peter Denning at Purdue University is developing mathematical models of data security in a computer system. His work promises to provide important insight into the future design of secure operating systems and into new computer architecture concepts which may be needed to guarantee the privacy of stored files.

National and International Progams

The National and International Programs Directorate comprises most, though not all, of the so-called "big science" programs of the Foundation. Covering a variety of activities, the directorate's programs are particularly strong in oceanography, the atmospheric sciences, and astronomy.

With some exceptions, the programs of the directorate depend on unsolicited proposals, which are reviewed and evaluated by peers and staff in standard NSF fashion. Interdisciplinary projects are common and require especially careful review. In addition to the scientific reviews, however, the proposals often require reviews for logistic feasibility and evaluation of international aspects and implications. And, in the national programs, the proposed projects must be fitted into the scope and objectives of that particular program as well.

Certain activities of the directorate are carried out under contracts or interagency agreements, for example, the support for the five National Research Centers, the Deep Sea Drilling Project, and the logistic support for the U.S. Antarctic Research Program. These typical aspects of the directorate's activities require unusual involvement by the staff in the management of programs. Indeed, intensive participation by the program staff is a main characteristic of the directorate's activities.

Highlights of activities in fiscal year 1974 include:

- Initiation of the construction of two new oceanographic research vessels, one of them funded with fiscal year 1974 appropriations, as replacements for older ships in the "academic fleet."
- Completion of the Pacific phase of the Geochemical Ocean Sections Study, a project of the International Decade of Ocean Exploration, to collect baseline data along profiles of major oceanic bodies.
- Initiation of construction at the site of the Very Large Array radio telescope in New Mexico, along with the award of several contracts for hardware.
- Initiation of limited observations on the new 4-meter Mayall Telescope at Kitt Peak National Observatory, the second largest operating telescope in the world.
- Delivery of three new ski-equipped LC-130R transport aircraft for use in the antarctic program and transfer of the specially constructed antarctic research ship *Eltanin*, now *Islas Orcadas*, to Argentina for joint use by Argentine and U.S. investigators.
- The establishment, shortly before the end of the fiscal year, of an Office for Climate Dynamics which, in cooperation with other elements of the Government, will focus attention on long-term variations in world climate.

The fuel crisis had major impact on several programs, especially those requiring ships and aircraft and those with major installations to maintain. A redistribution of funds was required in many cases to cover the unexpected increases in fuel costs.

In the atmosphere of detente, the Foundation's international cooperative science activities continued to expand, notably with the U.S.S.R. and other East European nations. Programs with the People's Republic of China, Japan, and Latin American nations were also at a high level of activity. International projects in energy research and development received special attention, including a series of visits by U.S. scientists to countries engaged in the exploration of alternative forms of energy.

NATIONAL AND SPECIAL RESEARCH PROGRAMS

Several areas of research are of such broad scope that they require special organization to assure the planning, management, funding, and logistics essential to their success. Among the factors that may determine that organizational need are: international cooperation, coordination with other agencies of Government, a relationship to a specific geographic region, and interdisciplinary scientific investigations. Research programs and research support activities falling in this category are designated by the Foundation as National or Special Research Programs and are reported here.

Table 3

National and Special Research Programs
Fiscal Years 1972, 1973 and 1974

[Dollars in millions]

	Fiscal year 1972		Fiscal year 1973		Fiscal year 1974	
	Number	Amount	Number	Amount	Number	Amount
International Biological Program	38	$ 9.44	30	$ 9.20	36	$ 8.82
Global Atmospheric Research Program	37	2.39	55	3.45	51	3.86
International Decade of Ocean Exploration	102	19.67	92	16.94	116	13.79
Arctic Research Program	61	3.54	62	3.43	46	3.87
U.S. Antarctic Research Program	139	27.00	130	44.00*	110	24.74
Oceanographic Facilities and Support	65	14.52	62	10.99	86	18.23
Ocean Sediment Coring Program	8	9.26	24	9.59	8	11.08
1973 Solar Eclipse Support	2	.06	10	.68	1	.04
Experimental R&D Incentives Program	0	0	78	11.89	70	10.55
National R&D Assessment Program	0	0	50	2.29	23	1.95
Science and Technology Policy Research	0	0	0	0	21	1.01
Energy R&D Policy Research	0	0	0	0	35	2.52
TOTAL	**452**	**$85.88**	**593**	**$112.46**	**603**	**$100.46**

* Includes Supplemental Appropriation $19.74 million for procurement of three ski-equipped aircraft.

INTERNATIONAL BIOLOGICAL PROGRAM*

Fiscal year 1974 was the final year of the International Biological Program (IBP). The program was initiated under the sponsorship of a National Academy of Sciences committee in an ambitious effort to ascertain how natural systems function and to elucidate man's role within and his effects upon several major ecosystems. (The results of the IBP will be reported in some detail in an Academy publication to be issued this year.) Briefly, major contributions were made in a number of general areas:

- Development of a data base in several ecosystems on the production of organic material and the fluxes and rates of matter and energy transfer.

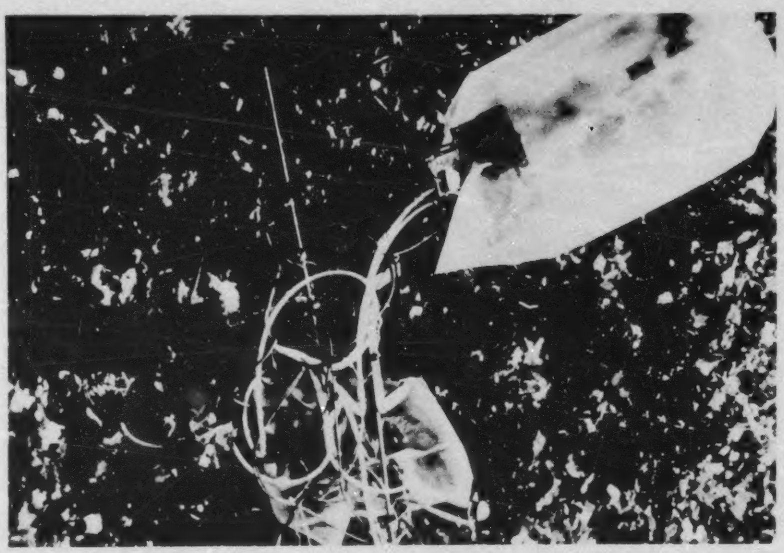
- Development of mathematical models that contain a level of predictability not previously available.

- Development of a well-trained cadre of young scientists who are committed to furthering our understanding of complex ecosystems.

Moreover, information developed during IBP has been put to use rapidly by Federal, State, and private groups. As we enter an era in which we become increasingly dependent upon national energy sources and wise land management practices, the scientific contributions of the IBP assume a timeliness and practicality not foreseen at the initiation of the program.

In the course of the IBP research, a great deal of effort was focused on analysis of productivity, its environmental controls, and the patterns and rates of nutrient, carbon, and energy flow through representative systems. For example, at the level of gross primary production there are major differences in productivity of contrasting ecosystems—highly understandable as a result of differences in temperature, available water, etc. But much of the captured solar energy must be used to maintain the community and is lost in autotrophic and heterotrophic respiration, leaving net ecosystem production values which have a much narrower range than those for gross production. The metabolic ratios suggest similar efficiencies and thus commonality of performance among the divergent systems.

The concern with energy flows through ecosystems forced attention to the need for data on some very difficult components, such as root growth and turnover, which previously had been largely ignored. Ecologists had known for some time that much of the "action" in forests and grasslands takes place below the soil surface, but few quantitative data were available. Measurements



The exchange of gases in photosynthesis in a deciduous forest is among the thousands of measurements made in forests, grasslands, desert, and tundra as part of the International Biological Program.

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* Although administered by the Research Directorate, IBP is included here because of its identification as one of the Foundation's National and Special Research Programs.

from the biome studies show belowground activity significantly higher than anticipated. For example, in one eastern deciduous forest current data indicate that more than 50 percent of the new photosynthetic production is utilized below ground for root growth. Even more of the annual energy and nutrient flux in these forests is accounted by root turnover, organic root exudates, and microbial activity.

In the more arid shortgrass prairie, co-dominance of two grass species which utilize different photosynthetic pathways (C3 and C4) leads to more efficient use of resources and greater total forage yields than would be possible with either species alone. The overwhelming importance of the decomposer subsystem, a sector highly sensitive to temperature and moisture, in processing organic debris and making nutrients available points out the critical nature of understanding how environmental stresses, such as those associated with energy and water, affect these ecosystems. The role of the littoral, or near-shore, zone in the overall productivity of lakes is apparently analogous to the relationships that estuaries bear to the ocean. That is, the littoral zone supplies most of the plant organic matter upon which the various lake food chains are based.

IBP findings in the area of nutrient cycling are as wide ranging and important as they are in ecosystem productivity. Strategies vary widely among ecosystems. In forests, nutrients are generally tightly conserved, but contrasts exist between coniferous forests, which fulfill a substantial proportion of their nutrient requirements by internal redistribution within individual trees, and deciduous forests, which cycle a much larger proportion of their nutrients through the annual litterfall-decomposition-uptake linkages. In deserts, nitrogen fixation is high (in great part due to blue-green algae in the soil) but, because of the alkaline nature of the soil and low levels of microbial activity, much of the nitrogen is lost to the atmosphere as ammonia.

The concept of a single, huge model of a forest or grassland to answer all scientific and practical needs has long since given way to the understanding that models must be built at a scale of complexity and temporal and spatial resolution needed to test a specific hypothesis or answer a specific question. One important strategy that has been widely used, especially with larger models, is the preparation of modules or submodels that can be combined in various ways and modified without the necessity of altering the entire model.

The proof of these models is, of course, in their usefulness in science (structuring information and testing hypotheses) and in problem solving—such as assisting in resolution of land management conflicts. They have proved valuable in both roles. For example, productivity and carbon cycling models for several biomes were utilized to examine the effects of climatic changes such as might be associated with an SST fleet. All performed well and provided similar answers, although validation of their predictions would, of course, be difficult. A hydrology-nutrient transport model developed by the eastern deciduous forest biome is being used to examine lead movement and accumulation in ecosystems. Models developed in the desert and tundra biomes have been used to predict the effects of increased off-road vehicular traffic.

The Foundation plans to continue four of the five biome studies at a decreased level of support for one or more years beyond the official end of IBP. New research in ecosystem analysis can be expected to draw very heavily upon the massive data base, concepts, and personnel developed in order to explore the many opportunities for research provided by this pioneering program.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM (GARP)*

The major effort of this program during fiscal year 1974 was preparation for the GARP Atlantic Tropical Experiment (GATE) that began on June 17, 1974. The scientific objectives of GATE are to: (1) estimate the effects of small-scale tropical weather systems such as cumulus cloud clusters on large-scale circulations, especially the general circulation of the atmosphere, and (2) advance the development of numerical modeling and prediction models to improve weather forecasting, particularly in the mid-latitudes.

The tropics are unique for there, in the oceans, most of the heat received from the Sun as short-wave radiation is stored. This energy is transferred into the boundary layer of the atmosphere as latent heat in the form of water vapor. The redistribution of the energy in the boundary layer occurs in spurtlike fashion through the atmosphere in cumulus clouds that become embedded in larger scale systems. The study and understanding of these cumulus systems so they can be characterized for use in atmospheric general circulation modeling is at the heart of GATE.

NSF's role in the U.S. participation in GARP is to provide support to the academic community, where much of the scientific expertise lies. About two-thirds of the awards made in GARP this year were in support of GATE. This GATE activity included support for 20 universities and research groups, as well as funds to place radar (operated by MIT), upper air, surface, and subsurface observing systems and associated data processing

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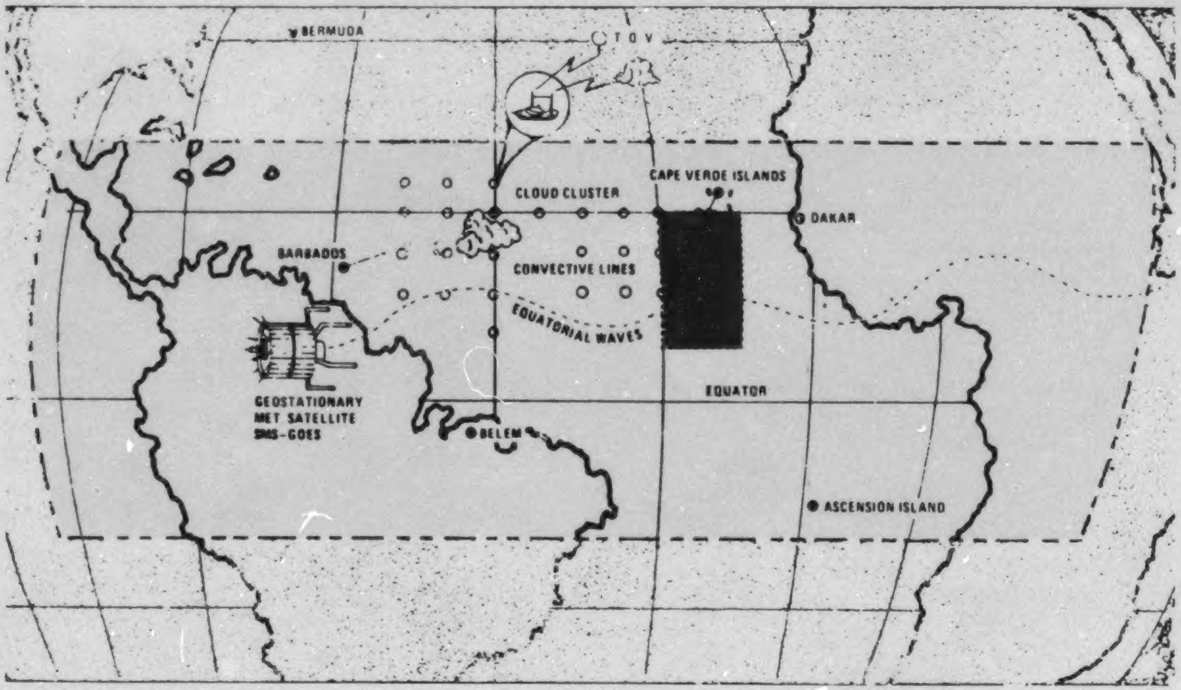
* Although administered by the Research Directorate, GARP is included here because of its identification as one of the Foundation's National and Special Research Programs.



Huge amounts of atmospheric and oceanic data from a 16,800,000-square-mile segment of the world stretching across the Atlantic Ocean from Africa through South and Central America were accumulated in the summer of 1974 under the international GARP Atlantic Tropical Experiment. NSF-funded experiments were concentrated in the ocean area west of Dakar.

equipment on the University of Miami ship RV *Gilliss* and to place a boundary layer system and data processing equipment from the University of Virginia on the USCGC *Dallas*. Support was provided to the University of Oklahoma to help the National Center for Atmospheric Research (NCAR) in its U.S. aircraft data management program. GATE also has been supported by NCAR and NSF's Office of Oceanographic Facilities and Support.

GATE is truly an international endeavor—from its initial planning to its execution and ultimate analyses of data. It represents the best, most integrated example of international big science to date. It is too early to report on definite scientific findings, but early indications are that many unexpected results are turning up.

A much smaller GARP field experiment, the Air Mass Modification Experiment (AMTEX), took place in the East China Sea during February 1974. This Japanese-led experiment had U.S. participation from the University of California, San Diego, Purdue University, Texas A&M University, Woods Hole Oceanographic Institution, and NCAR. Another field phase will be conducted in February 1975. Other activities supported by GARP in fiscal year 1974 included modeling of the general atmospheric circulation and clouds, studies of turbulence and predictability, and climate research.

INTERNATIONAL DECADE OF OCEAN EXPLORATION

The Office for the International Decade of Ocean Exploration (IDOE) is in its fourth year of providing support for large, multidisciplinary, international research projects on living and nonliving marine resources, ocean circulation, and the effect of the oceans on a global climate and marine environmental quality.

The Seabed Assessment Program supports studies on continental margins, deep seabeds, and mid-oceanic ridges in order to identify new locations and processes that produce natural resources, particularly petroleum and hard minerals. Fieldwork for geophysical and geological surveys of the African continental margin was completed in 1973. Scientists mapped large sediment-filled basins and belts of salt diapiric structures, some of which were previously unreported, and none of which has been completely mapped before. These are identified as potential sources for future petroleum production in deep water. Complementary work under way in early 1974 off Brazil and Argentina has also identified geological structures associated with large-scale oil accumulation.

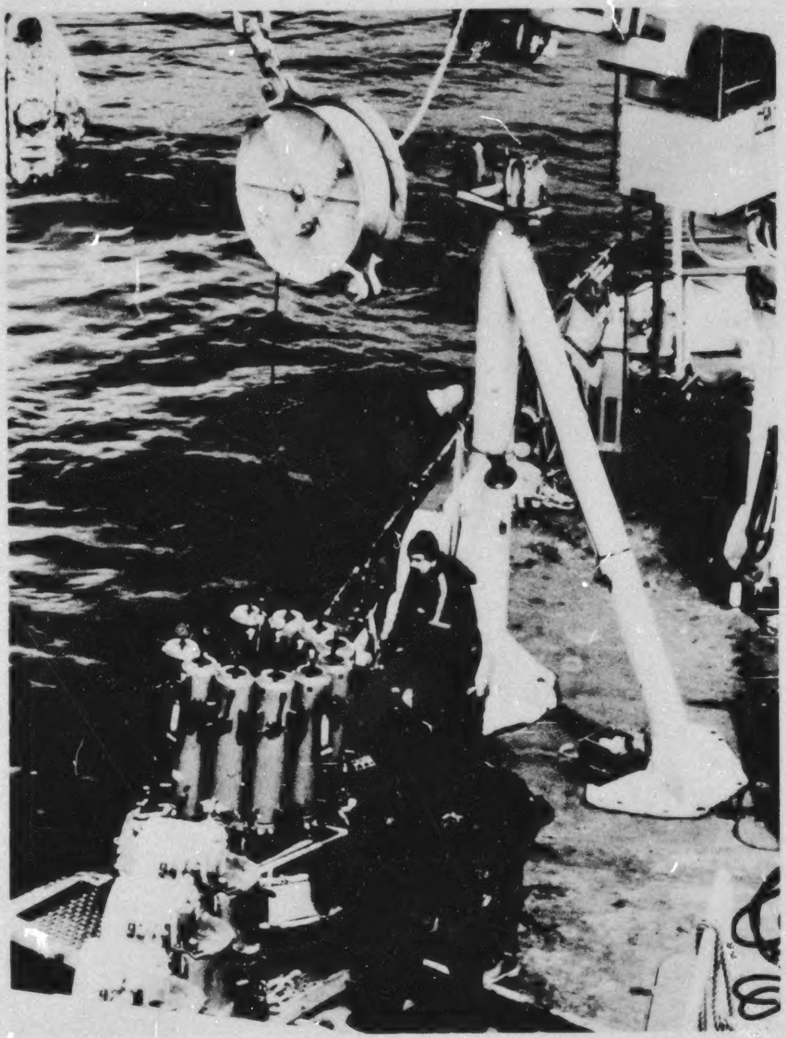
Understanding the origin of metalliferous ores and metal-bearing sediments is the goal of projects on active spreading zones in the deep ocean, including the mid-Atlantic Ridge and the East Pacific Rise. Highly metalliferous sediments, a potential source of heavy metals, have been identified in the Bauer Basin, located near the East Pacific Rise. Studies indicate that these sediments may consist of distinct manganese, or iron-rich phases, as well as nickel and cobalt. Preliminary site surveys and initial dives by French submersibles were completed on the mid-Atlantic Ridge during the summer of 1973 and resulted in a preliminary geologic picture of the research site. Firsthand observations, direct sampling, and photographs taken by teams of American and French scientists during approximately 50 dives in the summer of 1974 are under laboratory study.

Results from the Environmental Forecasting program will provide the basis for improved and extended forecasts of weather, climate, and ocean circulation. For example, investigators in the North Pacific Experiment (NORPAX) found that it was possible to anticipate the onset of El Niño, the long-term warming of surface waters off Peru, by 3 to 8 months by identifying conditions associated with fluctuations in equatorial ocean circulation.

Medium-scale eddies in general ocean circulation are thought to play a key role in the effect exerted by the oceans on weather and climate. Data from the Mid-Ocean Dynamics (MODE) field experiment, completed in mid-1973, have made it possible to describe an eddy roughly 80 miles in diameter with speeds 100 times faster than the average circulation of the deep Atlantic Ocean.

Researchers in the Climate: Long-Term Investigation, Mapping and Prediction (CLIMAP) program are seeking clues to past climatic trends by examining the historical changes in ocean current patterns, water mass properties, and sea-surface temperatures in the world's oceans. Reconstruction of past sea-surface temperatures from fossil evidence in deep sea sediment cores suggests that there are major and minor climatic cycles at intervals ranging from 85,000 to 2,000 years and, perhaps, even shorter periods.

The International Southern Ocean Study (ISOS), initiated in fiscal year 1974, will focus on the Antarctic Circumpolar Current. This current is the main vehicle for exchanging heat, mass, and nutrient chemicals between the Antarctic and the



An ocean bottom measuring device is lowered from a research vessel during the Mid-Ocean Dynamics Experiment (MODE) to help determine the circulation of eddies in the Atlantic Ocean.

Atlantic, Indian, and Pacific Oceans.

In the Environmental Quality program, the Pacific phase of the Geochemical Ocean Sections Study (GEOSECS) was completed in June 1974, having taken water samples and direct measurements at 180 locations between the Aleutian Islands and the Antarctic and between Tokyo and San Diego. Radioisotopic and trace element data are providing the basis for quantitative studies of ocean diffusion and mixing against which future distribution of fission and other waste products in the sea can be evaluated.

Projects designed to identify the mechanisms controlling the rates and paths by which pollutants enter the oceans have found concentrations of mercury, cadmium, and lead in the water, biota, suspended particulates, and marsh sediments of the inner continental shelf stretching from South Carolina to Florida. Highest concentrations were found in the sediments. Trace metals, petroleum, and chlorinated hydrocarbons were detected in the North Atlantic air and water. Tar lumps, suspected to originate from tanker washings, were also found, as was Freon, which is used as an aerosol propellant.

Plastic cylinders suspended in the sea will provide controlled environments for examining the effects on marine organisms of persistent low-level exposure to pollutants in the Controlled Ecosystem Pollution Experiment (CEPEX). Preliminary results from 1/4-scale models indicate that the full-scale enclosures (10 meters in diameter by 30 meters deep) will be suitable for enclosing communities of bacteria, phytoplankton, and zooplankton identical to those in the natural environment. Full-scale enclosures are under construction and will be launched in 1974.

The JOINT-I field experiment, a large-scale oceanographic-meteorological study of coastal upwelling off the coast of West Africa, was completed in June 1974. Scientists aboard ships from nine countries sought to understand the key features driving and controlling the upwelling process so vital to the world's fisheries. The goal of this Living Resources project is to enable prediction of the upwelling ecosystem by monitoring specific biological, physical, and meteorological variables.

During 1973, a number of IDOE projects, including the Mid-Ocean Dynamics Experiment, GEOSECS, and selected projects in marine geology and geophysics, formed the basis for several projects included in the U.S./U.S.S.R. Agreement on Studies of the World Ocean.

POLAR PROGRAMS

In the Arctic, the Tundra Biome project of the International Biological Program completed its fourth and final year in 1974. Its objective has been to develop a predictive understanding of how the tundra operates and to bring environmental knowledge to bear on problems of degradation, maintenance, and restoration of the temperature-sensitive, cold-dominated tundra and taiga ecosystems. Workshops in the United States and an international symposium at Abisko, Sweden, capped the project, whose major results will be reported in three volumes over the next 2 to 4 years.

The Man-in-the-Arctic project is producing social and economic data to help Alaska cope with its rapidly developing industry and with such far-reaching social changes as those caused by the Native Claims Settlement Act. In 1974, following a year of planning, studies got under way in four areas. Economics research, aimed at identifying and quantifying the structure of the Alaskan economy, included study of the major Alaskan industries and their interrelationships. Demographic studies, to develop population baseline data and to project changes, included census data processing and determination of growth trends by age, sex, and ethnic group. Ethnographic study of the changing role of Alaskan natives concentrated on problems of migration to urban areas. And political studies, dealing with the changing character of Alaska's political economy and culture, focused on Federal public land policies. The Institute of Social, Economic, and Government Research, University of Alaska, is carrying out the program in cooperation with other institutions.

The objective of the Greenland Ice Sheet Project, to construct a record of past climate, is similar to an objective of the antarctic program. Main elements of this international project are ice core drilling, radar sounding of ice thickness, sampling of gases trapped in the ice, and measurement of ice movements. A 400-meter ice core drilled in 1974 will enable reconstruction of seasonal temperature variations over the past several thousand years.

The Arctic Ice Dynamics Joint Experiment (AIDJEX) continued preparation for the main experiment, which starts in spring of 1975. Objective of the project, which began in 1971, is to forecast ice movement and deformation and ocean-atmosphere heat exchange from a network of meteorological observation points. Preparation in 1974 for the main experiment included development of data buoys, a study of cracks (leads) in ice floes off Barrow, Alaska, and development of mathematical models.

Since the 1957-58 International Geophysical Year, when the United States and other nations began continuous research programs in the south polar region, scientists have been accumulating evidence that climatic fluctuations in Antarctica have major influence on global climatic changes. The ice-covered continent, part of a single, earthwide thermodynamic machine, cools arriving tropical air and sends it north to heat again. The great antarctic circumpolar ocean current, chilled by ice shelves, extends arms of cold water beyond the Equator. The ice thus markedly affects the atmosphere and the oceans. Its variation is in fact both a cause and an indicator of climatic variations.

Antarctic projects in glaciology, oceanography, and meteorology are aimed at analyzing this ice-ocean-air system. The objectives are to learn the history of antarctic glaciation and climate, to discover historical climate patterns, and to predict global climate through special observations in the polar regions.

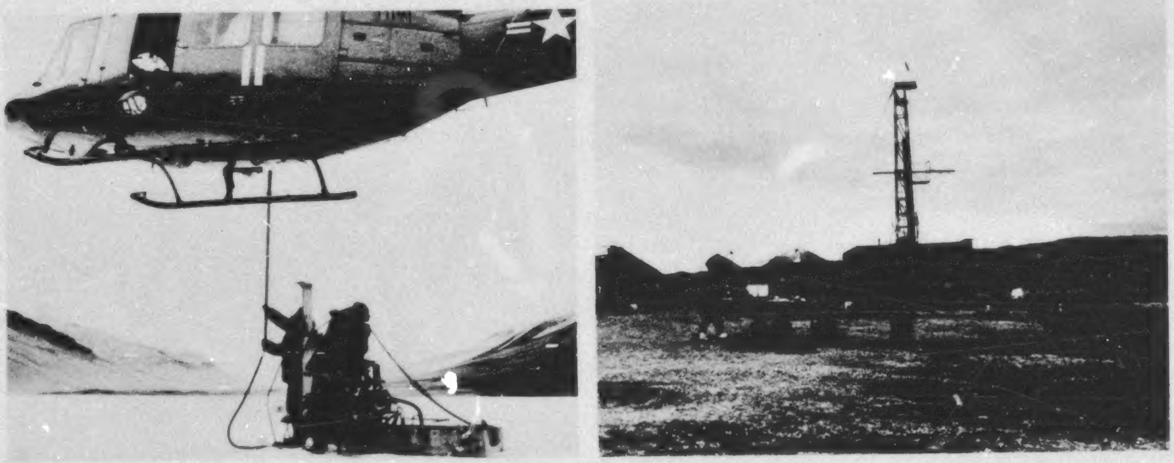
Glaciology in the 1973-74 austral summer research season centered on the Ross Ice Shelf, where researchers of six institutions gathered data on ice thickness and movement, internal structure, underlying water thickness, and ocean tides. A site was surveyed for future drilling through the shelf to the underlying water and sediment. Study of the resulting ice core will reveal the history of ice flow. Glacial geologic evidence collected in the McMurdo Sound region to date the retreat of the Ross Ice Shelf suggests that the shelf is steadily receding from its maximum position reached at the last ice age. Evidence of overall ice retreat was obtained through remeasurement of a glacier tongue that has been in an ice-free valley for 3 million years. The remeasurement showed that the glacier has begun retreating, probably only in the last 10 years. At the present rate of decay, this ancient glacier would vanish within 750 years.

Analysis of deep cores drilled into the sediments and rocks around McMurdo Sound this year in a joint Japan-New Zealand-United States project verifies that the ice-free valleys of southern Victoria Land once were marine fjords. The cores, a key to interpreting the complex geology of the McMurdo region, will aid in dating the glacial history of the area. A fringe benefit this year was discovery of viable organisms in the frozen cores.

To examine and quantify antarctic meteorological data, and to allow preparation of global circulation models, investigators from eight institutions are beginning an extensive new program at South Pole Station. The work includes laser-radar measurement of ice crystal distribution, acoustic profiling of winds, and measurement of sky radiation. The South Pole Station also serves as an environmental benchmark for monitoring atmospheric constituents, including pollutants.

Physical and biological oceanographic research in the southern ocean had been curtailed in 1972 when a budget cut triggered discontinuation of cruises by the ice-strengthened research ship USNS *Eltanin*. An arrangement was completed with Argentina, however, for joint operation and shared scientific use of the ship, and cruises will resume in mid-1974. The ship, renamed *Islas Orcadas*, will complete the circumpolar survey begun in 1962, with emphasis on the kinematics and dynamics of the circumpolar current, the formation of bottom water, the budgets of heat and momentum, and marine ecosystem analysis.

In addition to climate-oriented programs in glaciology, oceanography, and meteorology, major projects took place in upper atmosphere physics, terrestrial and marine biology, biomedicine, geophysics, and geology. Three new ski-equipped LC-130R transport airplanes were delivered for use in the program. The U.S. Navy and a civilian contractor provided logistic support.



A U.S. Navy helicopter (left) hovers while personnel of the joint Japan-New Zealand-United States project for drilling Antarctica's dry valleys prepare a drill engine for airlifting. During 1973-74, the Dry Valley Drilling Project obtained deep earth cores reaching to bedrock at eight sites in Antarctica, one of which is New Harbor (right), near McMurdo Sound. (Photos by U.S. Navy)

OCEANOGRAPHIC FACILITIES AND SUPPORT

Thirty ships operated by 15 academic and other nonprofit research institutions make up the "academic fleet." These ships are used principally in the conduct of federally supported research projects. Approximately 70 percent of the total operating costs of the fleet are provided by NSF's Office of Oceanographic Facilities and Support (OFS). In fiscal year 1974, OFS made awards totaling more than $13 million for fleet operations and shipboard technician support.

In 1974, more than 5,000 of the total of 8,000 ship-days scheduled by the academic fleet were for NSF projects. In addition to the fieldwork of individual grantees, interinstitutional and international "big science" projects generated heavy ship-time requirements. For example, five academic ships joined the international flotilla for Project GATE, a field project of the Global Atmospheric Research Program. Multiship operations were conducted in support of such diverse projects as geophysical investigations of the Nazca Plate off Western South America and biological studies of the JOINT-I expedition off West Africa.

Awards were also made for part-time use or charter of highly specialized facilities needed by NSF grantees. Among these were a deep submersible, an aircraft outfitted for oceanographic observations, and a ship equipped for multichannel seismic profiling.

The international fuel shortage during the winter of 1973-74 posed many problems for the fleet. However, a combination of hard work, good planning, and a little bit of luck kept delays to a minimum for academic research ships. A "fuel hotline" was established that served as a focal point for the institutions to exchange information on the availability and price of fuel in various ports and to obtain help with allocations and international reciprocity arrangements. A joint effort by OFS and the Office of Naval Research (ONR), the other principal supporting agency, provided emergency fuel to fleet ships on several occasions.

Construction of new ships and improvements to the existing fleet were also major concerns in 1974. When ship construction funds became available early in the fiscal year, an existing contract with the Woods Hole Oceanographic Institution for construction of a medium-sized research ship was amended to provide for the building of a second, identical ship. The first ship, *Oceanus*, will be assigned to Woods Hole upon completion in mid-1975. The second ship will be completed in late 1975 or early 1976. The designation of an operating institution for the second ship will be made in fiscal year 1975. Title to both ships will be retained by the Government.

The Nimitz Marine Facility Pier at the Scripps Institution of Oceanography, funded in 1972, was completed on schedule and dedicated in March 1974. The pier is one of only two in San Diego harbor having complete sewer and bilge water connections to avoid pollution of harbor waters with shipboard wastes.

Several awards were made to improve handling of oily wastes, bilges, and sewage on existing ships to bring them into compilance with environmental protection regulations. To establish priorities and arrange for funding of upgrading of this type, OFS and ONR initiated a joint program during 1974 to survey material condition and outfitting of the fleet.

OCEAN SEDIMENT CORING PROGRAM

The National Science Foundation funds the Deep Sea Drilling Project

The Nimitz Marine Facility Pier at San Diego, dedicated March 1974, has complete sewer and bilge water handling capabilities to help prevent pollution of harbor water. It is part of the marine operations facility of the Scripps Institution of Oceanography, University of California, San Diego. [Photo by University of California, San Diego]

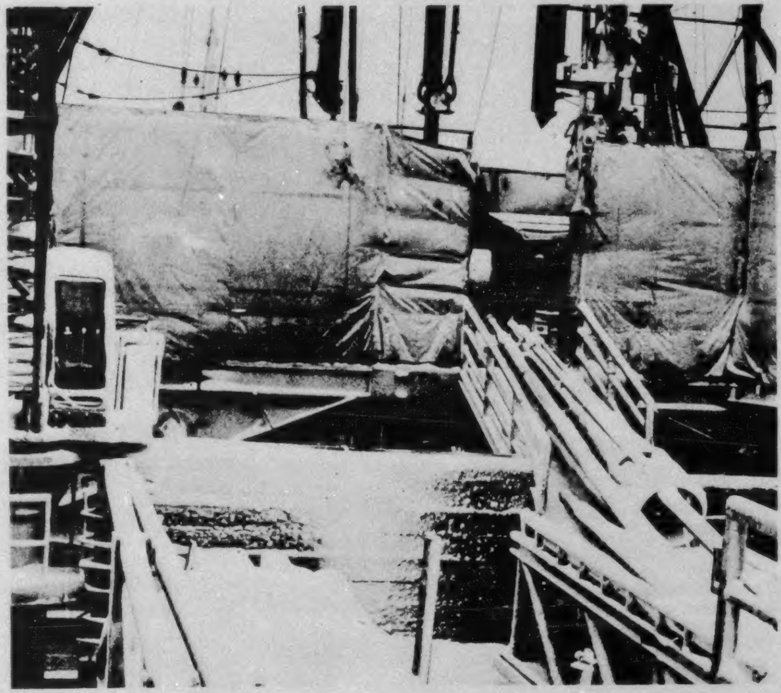
(DSDP) as part of the Ocean Sediment Coring Program. The DSDP is aimed primarily at learning more about the origin and history of the ocean basins and continents through drilling and coring of the sediments and rocks of the ocean floor. The prime contract for the management of this project is between the NSF and the University of California, with the Scripps Institution of Oceanography of the university delegated the responsibility for accomplishing the scientific objectives. The University of California subcontracts with Global Marine, Inc. (GMI) to perform the actual drilling and coring operations with GMI's ship *Glomar Challenger*.

Six years of operations were completed in August 1974. During this time, 489 holes were drilled at 332 sites in all the major oceans and seas except the ice-bound Arctic. During fiscal year 1974, 40 holes were drilled in the western, central, and eastern Pacific, the Antarctic, and the western North Atlantic oceans.

The results of drilling during fiscal year 1974 continued to help mold new concepts of the Earth's history. For example, evidence obtained during Leg 32 dates the opening of the South Atlantic Ocean basin with new accuracy at about 125 to 130 million years ago. At that time, the newly forming Atlantic Ocean must have looked very much like the modern Red Sea or the Gulf of California.

Leg 33 was designed to test the idea that linear island chains, such as the Line Islands chain, were formed by the movement of the entire Pacific Plate over fixed "hot spots." According to this theory, as the plate drifted over the "hot spot," old volcanoes would move with the plate and new ones would form over the "hot spot," eventually creating a long chain of volcanic islands. Data from three sites along the Line Islands chain showed that the "hot spot" theory cannot explain their origin.

Drilling on the Nazca Plate during Leg 34 encountered iron-enriched sediments above the highly fractured crystalline basement.



Snow blankets various pieces of drilling equipment as well as the wind-break constructed around the drill floor of the research vessel, *Glomar Challenger*, during drilling and coring operations on the Antarctic and Arctic expeditions of the Deep Sea Drilling Project, part of the Ocean Sediment Coring Program. (Photo by Scripps Institution of Oceanography)

Two antarctic legs (35 and 36) found evidence that glaciers occupied Antarctica at least 20 million years ago, and established that parts of the submerged Falkland Plateau are probably greater than 600 million years old.

Leg 37, west of the Azores in the Atlantic Ocean, achieved the deepest penetration of crystalline basement yet accomplished (more than 600 meters) and revealed sedimentary layers within the basalt.

In late February 1974, a Memorandum of Understanding was signed between NSF and the U.S.S.R. Academy of Sciences calling for a U.S.S.R. contribution to the Deep Sea Drilling Project of $1 million annually for a period of 5 years commencing in 1974. A similar agreement between NSF and the Deutsche Forschungsgemeinschaft of the Federal Republic of Germany is expected to be signed in early fiscal year 1975. Possibilities of similar future agreements with France, the United Kingdom, and Japan are being investigated.

A heave compensation system, designed to improve core samples and prolong bit life, was installed aboard *Challenger* in October and tested at sea. Inconsistent performance and technical problems prolonged the testing, but most problems had been solved at the end of the fiscal year. A sea floor locator was successfully completed and tested, and a new hard-rock laboratory was installed aboard the ship. Design was begun on a pressure core barrel that will maintain *in situ* pressure of cores throughout the coring process.

SOLAR ECLIPSE SUPPORT

A total eclipse of the Sun occurred on June 20, 1974. The path of the total phase of the eclipse touched the Earth at sunrise in the Indian Ocean southwest of Australia. It traveled in a northeasterly direction, passing over Amsterdam Island. At the southern latitude of 30° the path moved in a southeasterly direction towards Australia, and the northern limit of the path touched the southwestern corner of Australia before leaving the Earth's surface at sunset south of Tasmania. The maximum totality of the eclipse, 5 minutes and 8 seconds, occurred over the Indian Ocean. Totality over land masses occurred only at Amsterdam Island and Australia. Maximum totality over land was 4 minutes and 13 seconds and occurred at Point d'Entrecasteaux, West Australia.

The Foundation supported surveys of possible observing sites and identified those that were optimum for conducting ground-based experiments. Survey results and information on the characteristics of the solar eclipse were provided to scientists and serious amateur astronomers.

The Foundation coordinated national and international U.S. efforts related to this eclipse as it did for the 1973 eclipse. U.S. investigators who were interested in locating Australian scientists to collaborate on solar eclipse experiments were assisted by the Foundation. Two rocket-borne experiments were placed under the United States-Australia Agreement for Scientific and Technical Cooperation. The path of the eclipse crossed only a small portion of land in southwest Australia. Only a few U.S. scientists conducted experiments during the eclipse, and most were congregated within the small land area that was covered by clouds during the period of eclipse totality. Only one of two rocket-borne experiments achieved marginal success.

EXPERIMENTAL R&D INCENTIVES PROGRAM*

Begun in August 1972, the Experimental R&D Incentives Program was authorized by Congress to test potential incentives which the Federal Government might use to reduce barriers to innovation and to technology transfer in the civilian economy. During fiscal year 1974 some 70 grant and contract awards were made totaling some $10.6 million. The awards were divided among planning, support, and background studies ($2.2 million), and project exploratory experiments ($8.4 million). Seventy percent of the obligations were awarded for study, design, and experiment initiation in private sector areas, and 30 percent were awarded in public sector areas of interest. The largest single award was $3.0 million in an interagency agreement with the Veterans Administration (VA). This award is supporting a cooperative experiment by the NSF and the VA whereby the VA hospitals will clinically test and evaluate medical diagnostic ultrasonography imaging instruments of advanced design submitted by participating manufacturers. The experiment will test whether Federal action to shorten the clinical testing period for some kinds of medical instrumentation and bring them to market acceptance sooner is a sufficient incentive to encourage medical instrument manufacturers to increase their investments in instrumentation research and development.

Private Sector

Twenty-three awards were made by the Private Sector Office for background studies, including the operational phase of two cooperative university-industry R&D experimental projects that were initiated in fiscal year 1973. One major new experiment to gather information on incentives currently being used for stimulating technology utilization in ongoing Federal agency programs was initiated.

- **University-Industry Cooperative Research and Development.** The purpose of this experiment, begun with projects in fiscal year 1973, is to test the effectiveness of limited-duration Federal cost-sharing of university-industry cooperative applied research programs in stimulating industrial investment in research and development. Operational phase awards for two experimental projects were made in fiscal year 1974. One was to MIT for an applied research program with the polymer processing industry, and the other was to the MITRE Corp. to test the effectiveness of a university/industry/nonprofit research institute as an institutional combination for stimulating increased R&D investment by the New England electric utility industry.

The completion of Phase I—experiment definition—for three long-term and eight short-term experimental applied research projects in this area has provided the following observations and preliminary findings.

(1) Companies in specific industries have been able to work out agreements for cooperative applied research projects with the three long-term participant universities in this experiment under the stimulus of limited duration, Federal (NSF) cost-sharing.

(2) The long-term participating companies have reached agreements to commit their own funds to the cooperative research agreements to be spent, along with NSF cost-sharing funds, at the university or other institutions performing the research.

(3) Cooperative research agreements (acceptable to NSF) between the long-term participants, where more than one company is involved in a given research area, have been

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* Although the Office of Expermental R&D Incentives reports to the Office of the Director of the Foundation, it is included here because of its identification as one of the Foundation's National and Special Research Programs.

achieved, so far, only when the participating companies do not consider themselves as directly competing with each other in regard to the knowledge generated by the R&D efforts. When the participating companies compete with each other primarily on the basis of the innovations generated by the program, cooperative R&D agreements between a university and more than one company have consisted basically of one-to-one agreements with the university. These arrangements have not been considered compatible with the use of Federal funds under this cooperative R&D project.

(4) The cooperative research agreements which have been reached by the three long-term participants with their industrial partners resulted in industrial commitments for research and development ranging from approximately $0.80 to $1.40 for each $1 of Government (NSF) funding.

(5) Company financial commitments so far appear to be additions to their planned R&D budgets.

- **Federal Incentives for Stimulating Utilization of Civilian-Oriented, Federally Funded R&D Results.** Federal agencies funding civilian-oriented research and development have been using a variety of incentives to stimulate the utilization of the R&D results. Following a public request for proposals, NSF awarded a contract to conduct a natural experiment to determine the effectiveness of these incentives.

- **Centers for Invention and Innovation.** The purpose of this experiment is to test the incentive of limited-duration Federal funding of innovation centers at universities as an educational stimulus to the choice of careers in technical innovation. Three centers established under cooperative agreements with the Massachusetts Institute of Technology, Carnegie-Mellon University, and the University of Oregon are nearing the completion of Phase I (development of course structures, university protocol, center organization and staffing). Six courses have been developed, enrolling approximately 75 students (graduate and undergraduate level), and all of the centers are currently evaluating potential technological innovations submitted either internally or external to the centers' operation. Measures have been established to determine the effects of the center activities on producing increased technological innovation and on stimulating students to seek careers in technological innovation.

Public Sector

Building on background studies and experimental design efforts initiated in fiscal year 1973, the Public Sector Office established four major exploratory experiments in fiscal year 1974, with parallel evaluation efforts and support studies. These experiments, described below, have the near-term goal of exploring multi-institutional, intergovernmental strategies for increasing the use of R&D processes and techniques in the management and delivery of public services at the State and local level.

- **State Systems Addressed to State and Local Needs.** Two approaches utilizing State university systems are being explored. One focuses on the utilization of the University of Oklahoma's extension system as the vehicle for identifying and aggregating local municipal and rural county needs that can be solved through the utilization of R&D resources resident in the experimental area. The other will test the coupling of industrial R&D capability operated by the University of Tennessee.

- **Systems Addressed to State Legislatures.** This effort will examine the ways and means of coupling locally available R&D competence at Auburn University into the deliberations of a State legislature (Alabama) to help it plan and implement programs and legislation having technological content.

- **Multi-State Regional Systems.** The appropriate and effective utilization of research and development for public services hinges, at least in part, on geographic scale and density factors. This exploratory experiment will examine the viability of setting up a six-State mechanism to articulate the Rocky Mountain regionwide R&D needs and bring regional resources to bear on these needs.

- **Federal Technology Sharing Systems.** This project will couple a Federal Laboratory complex at the NASA-operated Mississippi Test Facility with the State governments of Mississippi and Louisiana to examine the degree to which such an arrangement can help the States effectively "buy" R&D systems support through their own funding sources or through national program resources.

In addition, the Public Sector Office has initiated a series of field studies and natural experiments looking at similar issues from the point of view of metropolitan areas, industry, and State legislative staff activities. In all cases, program efforts are evaluated in terms of their short-term implication for utilizing federally generated technologies, as well as their long-term potential regarding Federal policy action in support of better utilization of research and development, broadly construed, by State and local jurisdictions.

NATIONAL R&D ASSESSMENT PROGRAM*

Through the National R&D Assessment Program, the Foundation analyzes patterns of research and development and technological innovation; the incentives and decisions that underlie the existing patterns; and the implications that a choice of options will have in shaping future patterns of research and development and technological innovation.

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* Although the National R&D Assessment Program reports to the Office of the Director of the Foundation, it is included here because of its identification as one of the Foundation's National and Special Research Programs.

Work under this program can be roughly categorized in three broad areas. The first area examines past, present, and alternate future policies and practices of governments and assesses the relationships between policy options and the processes of technological innovation. Emphasis is placed on government policies manifested through expenditures, the tax system, and the legal framework. In addition, the experience of other industrialized nations in the area of science and technology policy is studied to determine implications for U.S. policy options. In fiscal year 1974, work was undertaken on the following specific subjects:

- Tax policies for R&D technological innovation.
- The relation between market structure and innovation.
- Government policies and the adoption of innovations in the integrated iron and steel industry
- A state-of-the-art review of the effects of regulation on technological innovation in the chemical and allied products industries.

The second area in this program is the study of socioeconomic consequences of technological innovation with the aim of establishing methodologies and estimates to measure and analyze the effects of technological changes. Specific studies started in fiscal year 1974 in this category are:

- Study of availability and quality of national statistics on research and development in selected OECD countries.
- The relationship of technological change and the demand for and supply of raw materials.
- International technology transfer by multinational enterprises.
- An evaluation of alternative methods for measuring the external and internal returns from technological innovation.
- Research and development, factor inputs, and productivity of the individual firm.
- Technological innovation and productivity/product-quality change by firms.
- The effectiveness of educational systems in facilitating adaptation to technical change.
- Economic analysis of contractual arrangements affecting firms' ability to capture returns from innovation.
- Effect of innovation on productivity in the service industries.

The third area explores innovation for a better understanding of the processes and decisions involved. An understanding of how the innovation process works is necessary to ascertain Federal options. Included in this area are the processes of innovation that may pertain to the private and public sector. In fiscal year 1974, work on the following subjects was started:

- Technological innovation and process development
- Role of the initial user in the industrial good innovation
- Diffusion of innovation: a longitudinal study in the shoe industry
- The adoption of innovation by local government
- Diffusion of technology in municipal governments
- Role of consortia in the national R&D effort

RESEARCH MANAGEMENT IMPROVEMENT PROGRAM

Recognizing the desirability of improving the management of federally supported research-related activities and research resources, the Foundation established the Research Management Improvement (RMI) Program in fiscal year 1973. In fiscal year 1974, the RMI program awarded support totaling $2,912,400 to 25 projects at universities, colleges, and other independent nonprofit research institutions. All of the supported projects can be classified into six major problem areas of research management:

(1) The administration of research in accordance with Federal requirements, regulations, policies, and procedures.

(2) Management of interdisciplinary research projects.

(3) Allocation of research resources—equipment, personnel, space, and support services.

(4) Planning and forecasting.

(5) Alternative strategies and organizations for research management.

(6) Competency-building in research management at all levels of university administration.

Almost half of the projects supported deal with category (2) above, the management of interdisciplinary research projects.

All of the projects supported in fiscal year 1973 are still under way. Four of them are nearing completion—at the California Institute of Technology, Oregon State University, the Upstate Medical Center of the State University of New York (SUNY), and the University of Southern California. Each of the four is concerned with a different problem area of research management.

Investigators at the California Institute of Technology are addressing the problem of rising costs for research support services. One study of departmental indirect costs will yield information on ways to provide improved research support services and effect economies in academic departmental organizational structures. A second investigation, concerned with the operation and maintenance of the physical plant, is an analysis of functions performed, together with the financial support patterns of each. In a third project investigators are studying the economic and engineering feasibility of an on-site power-generation plant as a means of offsetting the rapidly rising costs of electrical power.

Oregon State University is conducting a general review, analysis, and evaluation of its management of research. Investigators are examining the university's central research management activities; its management and coordination of research in all its centers, institutes, academic schools and departments, and other research organizations; its research associations with industry; and its research-related purchasing procedures and costs. An immediate result of this project will be a Research Handbook, designed primarily for use by university staff and faculty, but available to others too.

At the SUNY Upstate Medical Center, investigators are studying the feasibility of applying the Critical Path Method of planning to resource allocation for research projects. A theoretical model has been developed and is now being evaluated for its effectiveness and to determine what benefits the method may provide the individual investigator, the grants administration staff, and the Medical Center as a whole.

Investigators at the University of Southern California have examined the management of interdisciplinary research as it is practiced at major universities across the country. In particular, they have been analyzing those management policies, practices, and structures that facilitate the conduct of interdisciplinary research. From these data, they will develop new management techniques for such research and test their effectiveness in ongoing interdisciplinary research efforts at the university.

INSTITUTIONAL GRANTS FOR SCIENCE

Institutional Grants for Science provide general support for science annually to about one-fourth of the Nation's colleges and universities. Each grant is computed by applying a graduated arithmetical formula to the amount of an institution's Federal research support during the preceding year.

In fiscal year 1974, the Foundation made 678 institutional grants totaling $7 million. Each of the 50 States, the District of Columbia, Puerto Rico, Guam, and the Virgin Islands had one or more institutions receiving grants The grants ranged in size from $1,000 to $67,100, with the average being $10,300. Since the program began in fiscal year 1961, over 1,100 colleges and universities have received institutional grants amounting to $135 million.

Three-fourths of the fiscal year 1974 institutional grant funds were awarded to universities granting doctor's degrees, about one-sixth to master's grantors, and about one-tenth to colleges offering only undergraduate programs.

Institutional officials decide how the grant funds are to be spent. The methods of determining priorities with respect to the use of institutional grant funds vary considerably among the participating colleges and universities. There is an increasing tendency, however, to vest control of the funds in special committees whose primary purpose is to set institutional guidelines and criteria for allocating the funds within the various scientific disciplines.

As in previous years the purchase of equipment and supplies (including scientific books and periodicals) accounted for half the expenditures—considerably more than half for institutions offering only undergraduate programs. Salaries and stipends represent nearly 30 percent of the expenditures; doctoral-level institutions, many of which use the grants to encourage their younger faculty members to initiate research projects, spend a larger proportion of their funds for faculty salaries than do undergraduate colleges. The physical sciences have received about one-third of the funds, and the life sciences about one-fifth. Percentage allocations to social sciences and psychology tend to be higher in universities than in colleges where instructional equipment for natural science laboratories has the highest priority.

NATIONAL RESEARCH CENTERS

The Foundation provides support for the development and operation of five National Research Centers. Three of the centers are devoted to research in astronomy; one supports research in ionospheric physics as well as in astronomy; and one is a center for research in the atmospheric sciences. These centers have been established to meet national research needs in specific areas of science requiring facilities and operational support beyond the capabilities of individual educational and research institutions. They provide specialized equipment, facilities, and scientific expertise to aid all qualified scientists performing independent research of their own choosing.

Table 4

National Research Centers
Fiscal Years 1972, 1973, and 1974

	Fiscal year 1972			Fiscal year 1973			Fiscal year 1974		
	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total	Capital obligations	Research operations and support services	Total
National Astronomy and Ionosphere Center	$1,900,000	$ 2,787,500	$ 4,687,500	$ 399,000	$ 2,851,000	$ 3,250,000	$ 590,000	$ 2,610,000	$ 3,200,000
Kitt Peak National Observatory	456,000	7,243,881	7,699,881	70,000	7,780,000	7,850,000	792,000	7,008,000	7,800,000
Cerro Tololo Inter American Observatory	385,000	2,115,000	2,500,000	216,000	2,484,000	2,700,000	717,000	1,883,000	2,600,000
National Radio Astronomy Observatory	80,000	6,589,900	6,669,900	3,000,000	6,950,000	9,950,000	4,294,000	7,806,000	12,100,000
National Center for Atmospheric Research	1,000,000	17,177,416	18,177,416	—0—	16,000,000	16,000,000	1,148,000	16,352,000	17,500,000
TOTAL	**$3,821,000**	**$35,913,697**	**$39,734,697**	**$3,685,000**	**$36,065,000**	**$39,750,000**	**$7,541,000**	**$35,659,000**	**$43,200,000**

NATIONAL ASTRONOMY AND IONOSPHERE CENTER

The National Astronomy and Ionosphere Center (NAIC) is operated and managed by Cornell University under contract to the National Science Foundation. The primary NAIC observing instrument is a 1,000-foot-diameter spherical reflector located at a site 12 miles south of the city of Arecibo, P.R. NAIC provides administrative, engineering, and technical support for visitor and staff research programs at the observing site.

The upgrading of the 1,000-foot-diameter reflector observatory is nearing completion. Installation of the new reflector surface, consisting of 38,778 perforated aluminum panels, was completed in December 1973.

Final alignment of the new surface, scheduled for completion in December 1974, will permit high performance at wavelengths shorter than 10 centimeters, well below the previous short wavelength limit of 50 centimeters.

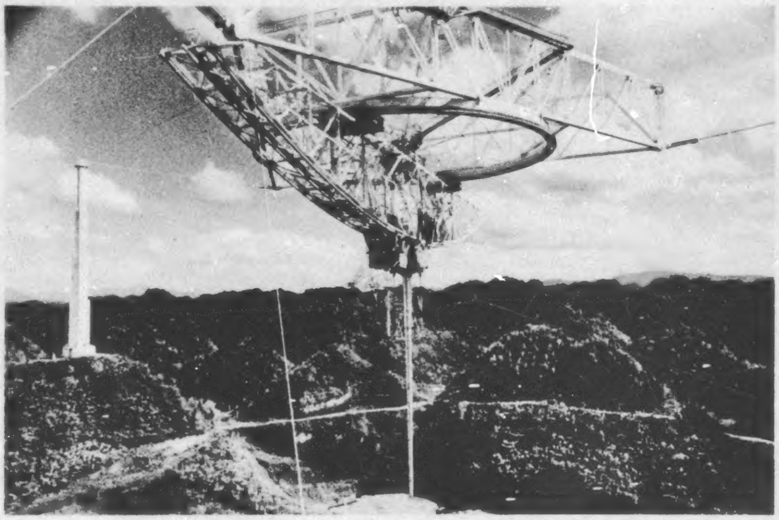
A major part of the upgrading program at NAIC is the installation of an S-band transmitter which will increase the planetary radar power level from 150 kilowatts at 430 MHz (megahertz, or a million cycles per second) to 450 kilowatts at 2.4 GHz (gigahertz, or a billion cycles per second). This capability is being sponsored by the National Aeronautics and Space Administration.

The upgraded facility will increase by a factor of 12 the frequency range available for scientific observations. Astronomers will be able to study the characteristics of interstellar molecules, pulsars, and remote galaxies, and to make high resolution maps of the surfaces of the planets Venus and Mercury.

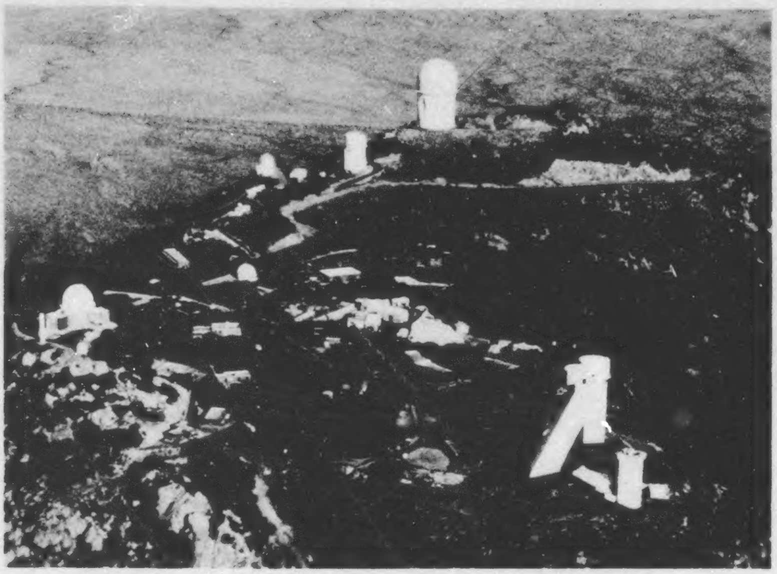
During fiscal year 1974, the NAIC observing facilities at Arecibo were used by 30 visiting investigators from 15 U.S. and foreign research and educational institutions. The number of public visitors to the observatory during the year exceeded 20,000.

KITT PEAK NATIONAL OBSERVATORY

The Kitt Peak National Observatory (KPNO) is operated under a contract with the National Science Foundation by the Association of Universities for Research in Astronomy, Inc., a nonprofit corporation representing a consortium of 12 U.S. universities. The primary mission of the observatory is to provide facilities for frontier research in solar, planetary, stellar, and galactic astronomy. Major ground-based telescopes, auxiliary instrumentation,



The suspended platform of the radar radio telescope at Arecibo, Puerto Rico, hangs above the newly paneled bowl below. The platform contains carriage houses, elevation rails, and a 430-megahertz antenna. [Photo by Cornell University]



The Kitt Peak National Observatory stands atop a mountain, 53 road miles from Tucson, Arizona. The new Solar Vacuum Telescope is housed in the tower at lower right, immediately adjacent to the McMath Solar Telescope. The Nicholas U. Mayall 4-meter telescope building is shown at the top. [Photo by Kitt Peak]

and related support facilities are available to staff scientists and to visiting astronomers from research and educational institutions throughout the United States and abroad. The observatory supports programs at its facilities on Kitt Peak, a 6,800-foot-high mountain located 40 miles west of Tucson, Ariz. The observatory headquarters in Tucson provide office, computing, and engineering facilities for visiting and staff scientists.

The major effort of KPNO during fiscal year 1974 was to bring into operation the 4-meter (158-inch) Mayall Telescope, the second largest operating telescope in the world. This powerful instrument, with its fast prime focus, permits astronomers to obtain photographs of faint objects in practical exposure times. Objects such as faint quasars and pulsars, as well as radio and X-ray sources radiating in the visible spectrum, are now within optical reach. The telescope's prime focus also has a wider field of view than any other major instrument. Consequently, one photographic plate provides significantly more sky coverage than any previously attainable. The "science" done per observing hour with this instrument will exceed by orders of magnitude that done by the large instruments of an earlier generation.

A new program being developed at KPNO will resolve a problem that astronomers have faced for many years: the production of large diffraction gratings. The gratings are used to separate, by diffraction, the many different wavelengths forming a beam of light. With larger gratings astronomers will be able to study the Sun and stars in greater detail than ever before. For many types of studies an increase in the size of a grating has the proportional effect of an increase in the size of the telescope primary mirror. Thus the same result may be achieved by using either a 150-inch telescope with a 24-inch grating, or a 300-inch telescope with a 12-inch grating. In January 1974 a grating ruling engine capable of ruling gratings up to 32 inches wide was transferred from the Massachusetts Institute of Technology to Kitt Peak National Observatory. During fiscal year 1975 production of large gratings will begin.

A solar vacuum telescope became fully operational in fiscal year 1974. The telescope provides daily high-resolution magnetic maps (magnetograms), spectroheliograms, and kinetograms of the full disc of the Sun.

During fiscal year 1974, the KPNO facilities were used by 257 astronomers, representing 78 U.S. and 48 foreign institutions from 10 countries. A minimum of 60 percent of time on KPNO telescopes is reserved for visiting scientists.

CERRO TOLOLO INTER-AMERICAN OBSERVATORY

The Cerro Tololo Inter-American Observatory (CTIO), operated under contract with the National Science Foundation by the Association of Universities for Research in Astronomy, Inc., was established in 1963 on Cerro Tololo, situated in the Chilean Andes approximately 300 miles north of Santiago and 50 miles inland from the coastal city of La Serena. The primary facilities of the observatory are located on the 7,200-foot-high Cerro Tololo mountain. With its dry, stable air and dark sky, Cerro Tololo offers what has been judged to be the best atmospheric "seeing" conditions for astronomical research available anywhere in the world.

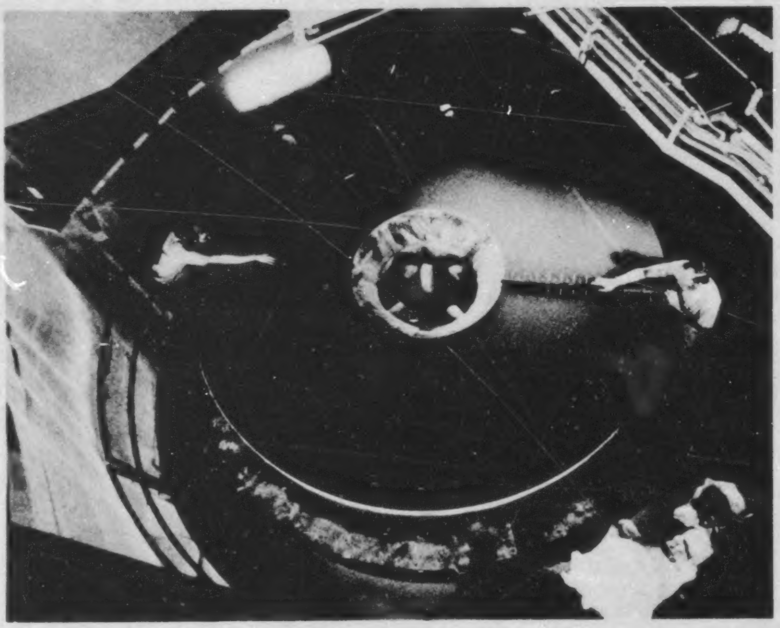
Situated at a southern latitude of 30°, CTIO provides ground-based telescopes, auxiliary instrumentation, and support facilities for studies of astronomical objects in that part of the sky not visible from the Northern Hemisphere. These include the southern Milky Way and our nearest external galaxies, the Magellanic Clouds.

During the past year, the 300-ton mount for the 4-meter (158-inch) telescope on Cerro Tololo was erected and balanced. Grinding and polishing of the CTIO 17-ton Cer-Vit mirror blank was completed at the Kitt Peak National Observatory in Tucson, Ariz. The mirror blank is the largest Cer-Vit blank ever figured and has the fastest focal ratio of any large mirror in existence.

While the quartz mirror for Kitt Peak's 4-meter Mayall Telescope required over 3 years of grinding and polishing, the CTIO blank was more accurately figured after only 24 months, with an additional 6 months for final polishing. Through the development of new and improved testing procedures pioneered in the KPNO optical shop, final testing has shown an optical resolution of better than 0.1 arc seconds—the most accurately figured large mirror blank ever produced. The primary mirror is scheduled to arrive for installation at Cerro Tololo in early fall 1974 and "first light" should be acquired shortly afterward. This 4-meter telescope will be the largest telescope operating in the Southern Hemisphere, and along with its sister 4-meter telescope at Kitt Peak National Observatory, it will be the second largest telescope operating anywhere in the world.

The observatory also completed erection of a 1-meter instrument, an f/10 Ritchey-Chretien telescope of high optical quality, on loan from Yale University. This telescope should reduce substantially the pressure for observing time on the observatory's 1.5-meter telescope, which is now over-subscribed by more than 100 percent. The first plates were taken with the 1-meter in December 1973, and by mid-January it was operating routinely on a temporary pad. In early May 1974 the instrument was installed in the completed building.

During fiscal year 1974, 110 astronomers from 46 U.S. institutions and 10 foreign institutions conducted observation programs at CTIO. A minimum of 60 percent of the time available on CTIO telescopes was reserved for visiting scientists.



Technicians of the Kitt Peak Optical Department position reference scales on the new 4-meter mirror that is now installed at the Cerro Tololo Inter-American Observatory in Chile. The scales being used are part of a critical Foucault test necessary for final acceptance. [Photo by Kitt Peak]

NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory (NRAO) provides the facilities and equipment necessary to assure a strong national program in radio astronomy. It is operated for the Foundation by Associated Universities, Inc., a nonprofit corporation formed by nine northeastern universities.

NRAO headquarters are located in Charlottesville, Va. The principal observing site is at Green Bank, W. Va. In addition, there is a radio telescope at the Kitt Peak National Observatory in Arizona. The Very Large Array (VLA) radio telescope, currently under construction, will be located near Socorro, N. Mex.

The principal instrumentation at Green Bank includes a 300-foot meridian transit telescope, a 140-foot telescope, and a four-antenna radio interferometer. The instrument at Kitt Peak is a 36-foot telescope with surface and pointing tolerances that make it suitable for operation in the millimeter region of the radio spectrum.

The spectral line capability of the Green Bank interferometer has been enhanced with the addition of a digital delay system. A 500 to 700 MHz parametric amplifier receiver has been added to the "front ends" (input electronics) available at Green Bank. Four new 256-channel filter receivers have been added at the 36-foot telescope.

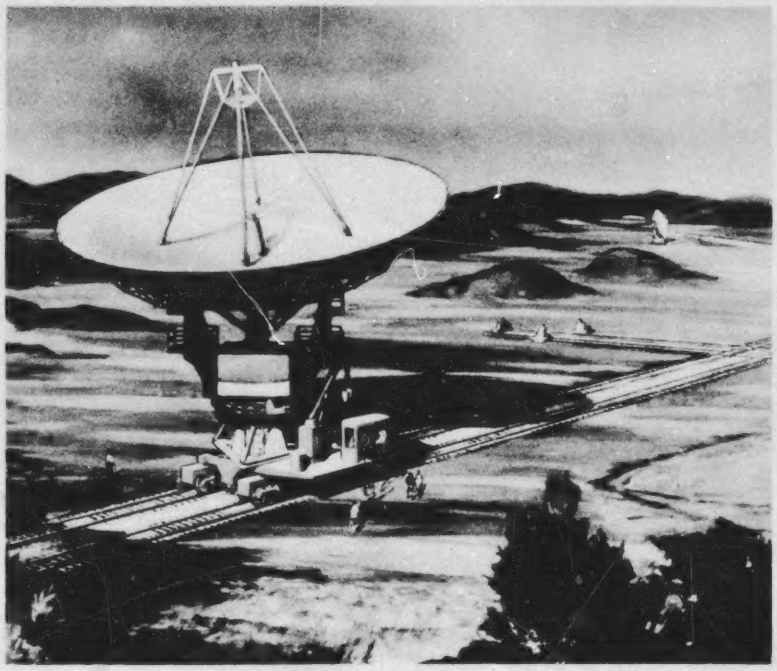
Very Long Baseline Interferometer (VLBI) experiments are conducted using stations located throughout the world. The NRAO Mark III VLBI tape processor is being upgraded to include more correlation channels and to allow simultaneous processing of tapes from three telescopes. A new hydrogen-maser frequency standard is being installed at Green Bank to improve phase stability for VLBI experiments.

At the 36-foot telescope at Kitt

Peak, the data collection system was replaced in fiscal year 1974 by a DDP11/40 computer, a high-speed multiplexer, and a new family of wide-band, ultrastable filter banks. The astrodome was recovered with new fabric.

The central IBM 360/50 computer was upgraded to an IBM 360/65 system in March 1974.

The VLA, located on the Plains of San Augustin, 50 miles west of Socorro, will consist of 27 antennas, each having a diameter of 82 feet and weighing 210 tons. Each antenna is movable along a system of railroad tracks arranged in the shape of an equiangular "Y." Contracts for the antennas and antenna transporter vehicles have been awarded, and railroad construction materials have been obtained. Right-of-way easements for the five tracts of land required for the initial phase of site construction have been obtained, and construction has been initiated. Subcontracts have been awarded for the synchronous and asynchronous subsystems, which comprise the continuum computer, and for the critical telescope components, including focusing feed mounts, subreflectors, and Cassegrain feeds.



On the Plains of San Augustin, 40 miles west of Socorro, New Mexico, 27 antennas, each with a diameter of 82 feet and weighing 210 tons, will move along a system of railroad tracks in the shape of a Y. When completed in the early 1980's, this system of interconnected radio telescopes, called the Very Large Array or VLA, will be the most advanced radio telescope in existence.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

The National Center for Atmospheric Research (NCAR) in Boulder, Colo. has two primary missions:

- To plan and conduct, in cooperation with universities and other organizations, atmospheric research programs beyond the scope of individual universities.
- To develop and operate selected research facilities in support of atmospheric research programs conducted by the Nation's scientists.

NCAR is operated for the Foundation by the University Corporation for Atmospheric Research, a nonprofit corporation formed by 42 U.S. and 2 Canadian universities. During calendar year 1973, NCAR research activities involved 175 visiting scientists and graduate students. Facility support was provided to 487 scientists from approximately 180 institutions.

During fiscal year 1974, a great deal of NCAR's effort was centered on two major field research programs: the National Hail Research Experiment and the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE). A third major effort involved observations of the solar corona with the NCAR White Light Coronagraph Experiment on board NASA's SKYLAB orbiting laboratory.

The National Hail Experiment has two major goals: to gain an improved understanding of the microphysics and dynamics of hailstorms and to test the feasibility of using cloud seeding as a tool to reduce hail damage. Some significant research accomplishments in the hail experiment are discussed under "Research Project Support Activities" earlier in this volume.

NCAR's principal efforts in the GARP program have been the development of global, three-dimensional models of the atmosphere, and participation in GATE, discussed under "National and Special Research Programs." The scientific aircraft plan for GATE was developed by NCAR scientists, working closely with colleagues in the United States and other countries. NCAR also developed an aircraft data management plan for the experiment, and established a team to handle the data. More than 40 scientists, technicians, engineers, flight crew members, and support people from NCAR participated in GATE field operations, which centered on a 200-square-mile area of the tropical Atlantic Ocean and were directed from an international control center in Dakar, Senegal.

During the 3 manned SKYLAB missions, the NCAR White Light Coronagraph obtained about 36,000 photographs of the solar corona, as well as high-quality photographs of comet Kohoutek. Some excellent photographs were obtained of the solar corona during both quiet periods and eruptions, and of the December 24 annular solar eclipse. Digital analysis of the photographs is expected to yield valuable new knowledge of the structure and evolution of the solar corona.

During the three manned Skylab Apollo missions, NCAR's white light coronagraph obtained about 36,000 photographs of the solar corona, including this photograph of an unusually large solar prominence erupting from the Sun on June 10, 1973. [Photo by NCAR]

SCIENCE INFORMATION ACTIVITIES

Early in fiscal year 1974, priorities were established for five programs for the Office of Science Information Service. These were: Research Support, National Information, User Support, Economics of Information, and Foreign Science. At the same time, funding for new publications, including periodicals, was terminated, and funds were devoted exclusively to support of research or development of improved, generalizable forms of science communication.

Of the five programs, the major emphasis remained in the Research Support Program. The National Information Program was redirected toward building capabilities for computer-based exchange of bibliographic information. Two new programs were added during the year: the User Support Program, which brought much needed emphasis on understanding the requirements of users as the basis for developing improved services; and an Economics of Information Program, which introduced a systematic effort to gather data on the costs and benefits of science communication activities.

Research Support Program

During fiscal year 1974, NSF gave final support to the university-centered information systems at Pittsburgh and Ohio State. These and similar systems at the University of Georgia, University of California, Los Angeles, and Lehigh University are continuing development and operations at their own expense. Final support was also provided for the development of the New England science information network under the auspices of the New England Board of Higher Education. Other research included initial work on ways to retrieve specific data or facts from texts of reports and, with MIT, work on ways to search dissimilar bibliographic data bases. Research completed by the Illinois Institute of Technology's Research Institute provided improved methods for manipulation of large data bases, such as those involved in the preparation of computer-based abstracting and indexing publications.

National Information Program

Final funding was provided for development of improved computer processing capabilities for chemical information provided by the Chemical Abstracts Service (CAS). Computerization of CAS has already yielded a fourfold expansion capacity (twice the coverage in half the time) since the project was undertaken in 1965. The program's new emphasis on developing operational compatibility among private and Federal science information systems was underlined in April 1974 by a conference of national leaders in the field of bibliographic control. Out of the conference came specific recommendations for the development of standards considered essential for the emergence of a national resource sharing network.

Another program initiative was to locate diverse and scattered information resources likely to be useful in dealing with the current energy shortage. The effort, which will continue at least through fiscal year 1976, was initiated with a pair of planning workshops. Participation by producers, processors, and users of energy R&D information, from both public and private sectors, resulted in specific recommendations for program actions.

User Support Program

Studies and experiments were originated in order to produce information for developing services that will be more responsive to user needs. One approach consisted of studies designed to increase understanding of the characteristics and requirements of users, with emphasis on needs of scientists and engineers working in industry. Data are sought that can be used by managers of services to introduce a wider range of information services that are self-supporting and responsive to user needs. Another approach focused on finding ways of reaching classes of users not now served by existing services. For example, in cooperation with public libraries in the San Francisco Bay area, the Lockheed Corp. is bringing on-line computer searching of nearly 20 scientific and technical information files to users who could not, by themselves, afford computer terminals. A similar activity is being sponsored in Pennsylvania under the Pennsylvania Science and Engineering Foundation.

Economics of Information Program

The first task under this new program was the development of a quantitative description of the scientific and technical information enterprise in the United States. Activities included initial development of a set of science information indicators, a description of the production and distribution of scientific information in the United States, and a state-of-the-art review of what is known about the economics of transferring information from one place to another. Also started was a basic assessment of the economic and policy issues related to public versus private responsibility for assuring economic viability of science information activities.

Foreign Science Program

Three important activities under this program in fiscal year 1974 included:

— Establishment of a U.S./U.S.S.R. Joint Working Group on Scientific and Technical Information. The U.S./U.S.S.R. joint activities are focused on: (a) development of a common format for the machine exchange of bibliographic data between systems in the two countries; (b) improvements in methods of forecasting developments related to scientific and technical information services; and (c) analyses of the costs and benefits of such services. During October 1973, 11 top Soviet science information managers and researchers participated in a seminar on these topics in Washington, D.C., and then toured U.S. science information facilities.

— Initiation of U.S./Japanese seminars, held in Tokyo on March 11-13, 1974, focused on the future of primary or hard-copy scientific journals.

— Formation of a U.S. Committee on International Scientific and Technical Information Programs at the National Academy of Sciences. This committee replaces two existing committees and will also serve as the U.S. national committee for UNISIST, which is a nonrepresentational acronym for the joint International Council on Scientific Unions-UNESCO study of the Feasibility of a World Science Information System.

INTERNATIONAL COOPERATIVE SCIENTIFIC ACTIVITIES

During fiscal year 1974, the National Science Foundation was named executive agency for a Science and Technology Agreement with New Zealand; it also assumed the role previously given to the Office of Science and Technology as executive agency for the U.S.-U.S.S.R. Agreement on Cooperation in the Fields of Science and Technology. This brings to 14 the number of bilateral science agreements for which NSF has management responsibility. Of these, the U.S.-Japan Cooperative Science Program, NSF's oldest bilateral activity, and the new U.S.-U.S.S.R. Science and Technology Program, are particularly active. The Japan program continued its high level of interaction, with cooperative projects and seminars on energy research and environmental pollution. The U.S.-U.S.S.R. program, with the Director of NSF serving as U.S. Chairman of the Joint Commission in his role as Science Adviser, has initiated activity in all of the program areas previously agreed upon for cooperation. These include chemical catalysis, application of computers to management, energy, microbiology, water resources, scientific and technical information, science policy, forestry research and technology, metrology and standardization, electrometallurgy, intellectual property, and special topics in physics. NSF made 65 awards in support of approved programs.

In addition to the 14 formal bilateral science programs, the Foundation worked informally with the Bulgarian and Czechoslovak Academies to develop approved programs. Also, as part of a new Cooperative Science Program with Latin America, NSF supported cooperative projects with scientific institutions in Colombia, Costa Rica, Venezuela, and Guatemala. The latter set of projects, in fact, intro-

Bilateral Science and Technology Agreements

Number of Approved Activities FY 1974

Country	Visiting Scientists U.S.	Visiting Scientists Foreign	Seminars	Cooperative Research Projects
Argentina	2	—	—	—
Australia	5	—	7	1
Brazil	7	—	1	9
Rep. of China	12	—	4	6
France	16	13	—	1
Hungary	6	2	1	5
India	14	18	—	—
Italy	8	—	4	24
Japan	8	—	28	29
Mexico	9	—	—	7
New Zealand	—	—	—	—
Romania	13	17	2	13
Spain	—	—	5	18
USSR	—	—	2	65
Total	100	50	54	178

Special Foreign Currency Program

Summary of Projects by Country

Country	Research Grants	Travel Grants	Translation Projects (Contracts)
Egypt	12	19	—
India	6	35	2
Pakistan	9	1	1
Poland	[illegible]	30	1
Tunisia	[illegible]	9	1
Yugoslavia	2	4	—
Total	41	98	5

U.S.-U.S.S.R. and East Europe Academy Exchange Programs

Visits Each Way*

Country	United States Scientists	United States Man-Months	Foreign Scientists	Foreign Man-Months
U.S.S.R.	27	61	36	117
Bulgaria	5	5	8	23
Czechoslovakia	19	31	7	14
Hungary	15	27	11	29
Poland	13	22	5	15
Romania	12	16	9	15
Yugoslavia	7	7	7	21
Total	98	169	83	234

*For the period May 1, 1973 to April 30, 1974.

duces the concept of cooperation through regional programs in countries where formal bilateral science agreements do not exist.

The Foundation's support of the National Academy of Sciences' (NAS) international activities continued. In particular, the exchange of scientists programs with the People's Republic of China and with the Academies of the U.S.S.R., Bulgaria, Czechoslovakia, Hungary, Poland, Romania, and Yugoslavia have been maintained and, in some cases, enlarged. During the year five groups of U.S. scientists visited the People's Republic of China and six groups of Chinese scientists reciprocated. These exchanges are undertaken through the Committee on Scholarly Communication with the People's Republic of China for which the Foundation provides partial support. Similarly, 98 U.S. scientists visited the U.S.S.R. and Eastern European nations under NAS exchange agreements. In turn, the United States received 83 scientists from that part of the world.

During the fiscal year, the United States-Israel Binational Science Foundation (BSF), with NSF's Director serving as its first Chairman of the Board, undertook its first full year of operation. Although the NSF does not financially support the BSF, it has provided staff assistance to the Director in his Board responsibilities and has provided reviewers for proposals being considered by the BSF.

The Foundation supported NAS membership and participation in the International Council of Scientific Unions and other international scientific organizations. The Academy's membership in and support of the International Institute for Applied Systems Analysis (IIASA), located in Austria, continues with funds provided by NSF. The Foundation has developed an in-house group of reviewers to study IIASA programs and proposals and to assist NSF in decisions relating to its policies and direction.

The increased emphasis on energy problems resulted in funds being made available to NSF to foster international cooperation in energy research and development. In cooperation with the Department of State and other U.S. Government agencies, NSF initiated a program of visits of U.S. scientists to countries actively engaged in exploring alternative forms of energy. Also, a program was initiated of binational and international seminars on energy research, especially solar and geothermal.

Special Foreign Currency Program for Scientific Research and Related Activities

The Foundation's Special Foreign Currency (SFC) Program for Scientific Research and Related Activities, using U.S.-owned excess currency, has supported cooperative research projects, seminars, and translations in Egypt, India, Pakistan, Poland, Tunisia, and Yugoslavia during the year. The SFC program in Yugoslavia terminated this year, however, because the U.S.-owned excess currencies in that nation have been exhausted. In fiscal year 1974, the Foundation awarded 41 grants for cooperative research and made 98 travel awards for activities in these countries. Translation support was given to five projects.

Under this program, the Foundation supported the visit of a U.S. team of specialists to Pakistan to participate with members of the new Pakistan Science Foundation (PSF) in developing plans and priorities for its operation. The PSF is expected to play a major role in the advancement of Pakistani science and technology.

Research Applications

In fiscal year 1974 the Research Applications Directorate completed the third year of operation of its RANN—Research Applied to National Needs—program. During this year RANN was pointed sharply toward national problems in energy, environment, and productivity.

An important purpose of this program is to shorten the time between the discoveries of science and their application in meeting human needs. Thus, RANN provides a key bridge between the Foundation's basic research programs and the development and operating programs of the Federal mission agencies and other important elements of the user community, including industry and government at State and local levels. RANN projects frequently are highly interdisciplinary efforts involving technologists, environmentalists, social scientists, and other specialists working as teams to serve the needs of decisionmakers representing all classes of users.

Because of the importance to RANN of the user community, a complementary program, Intergovernmental Science and Research Utilization, is also carried out in the Research Applications Directorate. Research utilization activities were broadened and strengthened during the year. Research utilization was also emphasized in a publication specifying guidelines for preparation of unsolicited RANN proposals.

The national energy crisis stimulated considerable expansion of this component of RANN research, and significant results were registered. Perhaps the most noteworthy was the construction and operation of experimental solar energy systems to augment the heating plants of four public schools at different locations in the United States. In addition, two solar heating and cooling laboratories were constructed, an experimental solar house was built, and three major feasibility studies of solar heating and cooling were completed under contract with industrial corporations. The results of these efforts were reported to more than 500 representatives of the building industry, architects, bankers, and city and State officials at a national workshop in June 1974.

Energy research in the RANN program also focused on other applications of solar energy as well as a number of other promising opportunities in geothermal energy and in approaches to more efficient and nonpolluting ways to meet growing energy needs.

RANN research in the environment is aimed at threats to the natural environment, such as trace contaminants resulting from man's activities, weather modification, and environmental management problems such as land and coastal zone uses. It also is aimed at threats to the manmade environment from earthquakes, fire, and other natural hazards.

Productivity efforts were pointed toward public sector productivity, including a whole spectrum of work aimed at better use of human and institutional resources, particularly in State and local government. Research in private sector productivity focused attention on opportunities for industry to use modern technology more efficiently in producing goods and services needed by a growing population, so as to inhibit inflation and improve the U.S. position in world trade.

Planning during fiscal year 1974 resulted in a decision to establish a fourth focus of RANN research, that of resources. This area will include research aimed at increasing renewable resources such as fiber and food and nonrenewable resources such as minerals and fossil fuels. By establishing arrangements for special attention in this area, the Foundation intends to emphasize the research efforts already under way and to utilize existing RANN relationships and techniques to encourage significant growth of these activities.

Table 5

Research Applied to National Needs and
Intergovernmental Science and Research Utilization
Fiscal Years 1972, 1973, and 1974

(Dollars in millions)

	Fiscal year 1972		Fiscal year 1973		Fiscal year 1974	
	Number	Amount	Number	Amount	Number	Amount
Research Applied to National Needs	**338**	**$53.77**	**616**	**$69.88**	**589**	**$75.08**
Advanced Energy Research and Technology	—0—	—0—	—0—	—0—	215	28.11
Advanced Technology Applications	163	18.35	262	28.94	131	15.60
Environmental Systems and Resources	98	19.45	148	22.50	112	17.17
Social Systems and Human Resources	25	11.28	122	13.35	74	10.40
Exploratory Research and Problem Assessment	52	4.69	84	5.09	57	3.80
Intergovernmental Science and Research Utilization	**43**	**1.08**	**54**	**1.00**	**26**	**.96**
Total	381	$54.85	670	$70.88	615	$76.04

ENERGY

The need to use the Nation's depletable energy resources more wisely has increased the urgency to strengthen innovative and imaginative research on alternative resources to meet our energy requirements. Consequently, the NSF in fiscal year 1974 established a separate division to direct the Energy Research and Technology Program. This program supports research focused on ensuring the availability of essential energy alternatives in selected applications before the end of this decade and on a substantially expanded scale in the next decade. These activities are integral elements of the total Federal energy effort.

Major progress was made during fiscal year 1974 in systems studies and analyses of U.S. energy production and use, in showing the potential of solar heating and cooling, and in advancing the technology of solar energy as a practical energy resource. Rapidly expanding research in geothermal energy increased understanding of the vast potential of this little used resource. Research in a variety of other energy technologies pointed clearly toward opportunities to increase the efficiency and effectiveness of U.S. energy utilization. In parallel with these studies, progress was made in undertaking energy-related technology assessments and in understanding the environmental, social, and intergovernmental impacts of energy on our national life.

Energy Systems

Research on energy systems is supported in order to identify new research targets; establish research priorities; recommend ways in which available resources should be applied to research needs; recommend appropriate modifications to ongoing research; and establish means for integrating established and proposed research projects. A multidisciplinary approach is employed to examine the technical, environmental, economic, societal, regulatory, and legal aspects of energy. These endeavors—in the program areas of resource analysis, energy conservation, data base and system modeling, comparative systems analysis, and regulatory and policy options—result in an analysis and assessment of the policy and regulatory options through which the most effective uses of energy for meeting our national needs may be provided.

Results of a number of these research projects in energy systems have already provided substantive input to energy policy decisions, and others promise to do so in the near future. In its consideration of the consequences of alternative regulatory policies for dealing with the natural gas shortage, the Congress included specialized assessments made on the basis of a model for natural gas policy studies that was developed at the Energy Laboratory at the Massachusetts Institute of Technology. The State of California adopted during fiscal year 1974 a landmark State Energy Resources Conservation and Development Act that incorporates many of the recommendations made by the Rand Corp. from its evaluation of measures for conserving energy. The close coordination of such energy systems activities with other portions of the Federal energy program is evidenced by the fact that both the Environmental Protection Agency and the Federal Energy Administration are now sponsoring extensions of this initial effort. Cooperative efforts of Brookhaven National Laboratory and the State University of New York to analyze the production, distribution, and consumption of energy for the New York City region produced results that were used for evaluating and establishing future policies by the New York City Interdepartmental Committee on Fuels and Public Utilities, as well as by other groups.

Research of a more direct nature includes studies by Richard Stein Associates, in conjunction with the New York City Board of Education, on energy conservation in school buildings. In spite of the initial high efficiency of energy utilization for this school system, the study showed that retrofitting existing school buildings can reduce energy consumption by 28 percent and that the careful design of new school buildings can reduce energy consumption by 50 percent. The significance of these savings prompted the New York City Board of Education to provide funds for two proof-of-concept demonstration experiments. Information on these results has been provided to other school districts. In another conservation study, research by AeroVironment Corporation using full-scale road tests and scale model wind tunnel tests at the California Institute of Technology show that a 17-percent improvement in miles per gallon at a speed of 55 mph is possible as a result of relatively simple streamlining. The full potential savings in this area are one billion gallons of fuel per year. A respectable portion of this appears achievable in the near future.

A final class of achievements relates to the dissemination and exchange of information between the research and user communities. Typical of this activity is the publication of a 550-page compilation of the supply, demand, conservation, and institutional concerns of energy that resulted from a conference at MIT. Another conference, held at the Ohio State University and based on the results of research on energy conservation in residential, commercial, and industrial buildings, was attended by more than 300 people from industry, trade organizations, government, and universities.

Solar Heating and Cooling of Buildings

Major strides were taken in fiscal year 1974 toward proving the concept of supplying substantial amounts of the Nation's energy needs by utilizing the heat of the Sun for heating and cooling of buildings. The significance of this potential contribution is seen in the fact that these uses account for about a quarter of the energy consumed in the United States, at an annual cost of more than 20 billion dollars.

During the year, three major feasibility studies of solar heating and cooling were completed under contract with industrial corporations; large experimental solar heating systems were installed in public schools at four different locations in the United States; and two solar heating laboratories were constructed. In addition, an experimental solar house was constructed as part of an effort to determine whether its technology could supply an answer to a building moratorium stemming from one city's lack of appropriate energy sources.

The feasibility studies, carried out by teams under the direction of General Electric Co., TRW Systems Group, and Westinghouse Corp., assembled comprehensive economic, social, environmental, and technical information on the potential utilization of solar heating and cooling in all types of buildings and all climates within the United States. The three concerns also recommended experiments to prove the concept and the viability of solar heating and cooling and to stimulate its widespread use. The results of the studies were reported to more than 500 representatives of the building industry, architects, bankers, and city and State officials at a workshop held in Washington, D.C., in June 1974.

The experimental systems installed in the four schools are among the largest solar heating systems in existence. They are as follows:

- Timonium Elementary School, Timonium, Md., 5,700 square feet of solar collectors. Contractor: AAI, Inc., Cockeysville, Md.
- North View Junior High School, Osseo, Minn., 5,000 square feet. Contractor: Honeywell, Inc., Minneapolis, Minn.
- Grover Cleveland Junior High School, Boston, Mass., 4,500 square feet. Contractor: General Electric Co., Valley Forge, Pa.
- Fauquier County Public High School, Warrenton, Va., 2,500 square feet. Contractor: Inter-Technology Corp., Warrenton, Va.

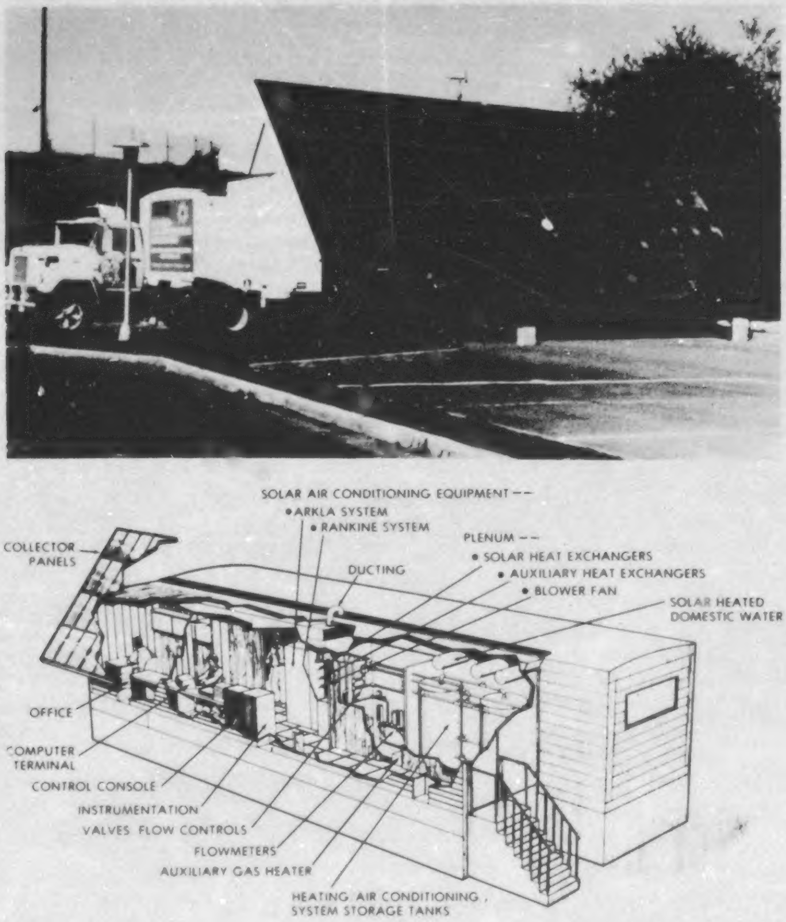
Follow-up year-long studies were initiated to obtain information on the performance, economics, and social and environmental factors relating to the four systems. Special attention was placed on the implications of these experiments for retrofitting of solar heating and cooling systems into existing buildings.

The two laboratories were constructed to accelerate the collection of data on solar heating and cooling. One, the size of a single-family dwelling, is at Colorado State University at Fort Collins, Colo. It is being operated to obtain a calibrated baseline system and to test advanced subsystems. The second laboratory is transportable and contains a completely integrated solar heating and hot water system, two types of cooling systems, and a weather station. This laboratory collects information on the availability of usable solar energy for heating and cooling under a wide variety of weather and environmental conditions at various locations in the United States.

These data and the results of proof-of-concept experiments will make it possible to design systems throughout the United States to meet specialized performance requirements on a large-scale basis.

The Foundation and the city of Colorado Springs, Colo., jointly sponsored the evaluation and testing of a solar house, followed by system

The Timonium Elementary School near Baltimore, Maryland, one of four schools that experimented with NSF-sponsored solar heating systems last year, was the first school in the Nation heated by solar energy. Solar heat is collected in water flowing through the rooftop panels, pumped into a storage tank, and then used to heat classrooms. [Photo by Aircraft Armaments, Inc.]


SOLAR AIR CONDITIONING EQUIPMENT --
• ARKLA SYSTEM
• RANKINE SYSTEM
PLENUM --
• SOLAR HEAT EXCHANGERS
• AUXILIARY HEAT EXCHANGERS
• BLOWER FAN
COLLECTOR PANELS
DUCTING
SOLAR HEATED DOMESTIC WATER
OFFICE
COMPUTER TERMINAL
CONTROL CONSOLE
INSTRUMENTATION
VALVES FLOW CONTROLS
FLOWMETERS
AUXILIARY GAS HEATER
HEATING AIR CONDITIONING, SYSTEM STORAGE TANKS

This mobile solar-heated and -cooled laboratory, built and operated by Honeywell of Minneapolis, is now collecting data on solar radiation and climate at different locations in the United States. These data will be useful for future designers of structures using solar energy.

testing and evaluation. The city initiative was stimulated by the need for alternative energy sources to end a building moratorium. A new feature being tested in this system is the use of a solar-augmented heat pump with large-scale energy storage.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) completed a comprehensive study of currently available solar heating and cooling design data and published it in the 1974 edition of the ASHRAE Guide, distributed to design engineers for use in calculations and preparation of drawings.

The National Bureau of Standards developed standardized test procedures to permit comparison of solar collectors and storage devices. The standards were documented in a publication to be distributed to investigators of NSF-supported projects concerned with improvements to solar collectors and storage devices. Their use in recording and collecting data will improve the possibility of comparing results of separate investigators working at different locations and institutions.

Twenty-three grants and contracts were awarded for innovative research projects on subsystems and systems for the application of solar energy to heating and cooling of buildings. These were the first awards made from 448 formal proposals that resulted from a widely distributed solicitation issued during fiscal year 1974.

Other Solar Energy

The solar energy program also supports research aimed at supplying significant contributions to national energy needs through wind energy, solar thermal conversion, bioconversion, photovoltaics, and ocean thermal energy conversion.

Design of the largest wind energy system initiated in the United States in the past 30 years was begun with NSF support during fiscal year 1974 by the Lewis Research Center of the National Aeronautics and Space Administration.

The University of Oklahoma constructed and began testing of a field modulated generator, capable of producing constant voltage and constant frequency output regardless of windmill speed. Other projects started include Princeton University's testing of a Sailwing rotor, a low-cost metal and fabric rotor for small wind systems, and an initial assessment of the status of wind data and prediction capability and requirements with the joint support of the National Oceanic and Atmospheric Administration and NSF. Heavy response was received to program solicitations for wind area research and for the preliminary design of wind energy systems generating up to 3 megawatts of electrical power.

In solar thermal conversion, testing began of a scale model parabolic trough collector module with an aperture of 4 feet by 14 feet. Construction of a prototype heliostat began and design efforts were initiated for a thermal cavity heat receiver of the most promising concept identified for a station generating 1,000 megawatts. Research led to proof of a technique to apply antireflection selective coatings to heat collecting units by chemical vapor deposition.

In bioconversion, an NSF-supported study by the Stanford Research Institute indicated that synthetic natural gas and electric energy might be produced on "energy farms" for costs on the order of $2 to $3 per million British thermal units (Btu's). This is approximately equivalent to $12 to $18 per barrel of crude oil. The costs might be significantly decreased by using such a facility to produce food and industrial chemical byproducts at the same time.

Economic and engineering feasibility studies were completed on the conversion of urban organic solid wastes to methane gas. Results indicated that methane can be produced in quantities and at costs that would be attractive to the natural gas industry. A proof-of-concept experiment was designed to provide the basis for defining a pilot plant facility that in operation would verify process feasibility and establish the basis for constructing full-scale facilities.

In photovoltaics—the use of solar cells to generate electricity—significant achievements included the successful growth of continuous ribbons of crystalline silicon. Both the rate of growth and the suitability of the resulting crystal for solar cell production represent major advances over existing methods. It is anticipated that this method lends itself best to streamlined processes for low-cost production of solar cells, possibly less than $500 per peak kilowatt of capability. In another project, a team of researchers at Southern Methodist University and Texas Instrument Co. successfully fabricated p-n junction polycrystalline solar cells on metallurgical silicon with greater than 2 percent efficiency.

Studies of ocean thermal power conversion indicated that satisfactory net efficiencies and competitive costs could be achieved in large floating powerplants generating more than 100 megawatts of electrical power. A parametric design system study was begun and heavy response was received to a program solicitation inviting proposals in six categories of ocean thermal research.

Other Energy Research and Technology

In addition to its interest in energy systems and solar energy, the NSF Energy Research and Technology Program includes work on geothermal energy, energy resources, energy conversion and storage, energy and fuel transportation, and advanced automotive propulsion.

In geothermal energy research, the Foundation in fiscal year 1974 was assigned the role of lead agency for coordination of Federal activities. An interagency panel was established with representation from the Department of the Interior, the Federal Energy Administration, the Atomic Energy Commission, the Federal Power Commission, the Environmental Protection Agency, the Council on Environmental Quality, the Department of Defense, and the NSF

Geophysical tests confirmed the existence of thermal anomaly near Marysville, Mont., and the drilling of a deep test hole was initiated. Temperature logs from 174 wells in New Mexico and adjoining States revealed a zone of high heat flow (greater than 2.5 heat flow units) running the length of the Rio Grande depression on its west side. These results were made available to the U.S. Geological Survey for an assessment of the geothermal potential of that region.

A joint project with Federal, State, and local government agencies provided first- and second-order topographic surveys of California's Imperial Valley. Geophysical, geochemical, and petrologic studies at the Dunes Anomaly in this valley revealed knowledge of the physical and chemical mechanisms by which geothermal fluids, such as hot brines, circulate in these zones.

A major geothermal drilling project was completed at Kilauea Volcano in Hawaii. The test hole, drilled more than 4,000 feet deep on the flank of the volcano, provided data on subsurface temperature and structure for use in assessment of the geothermal potential of Hawaii. A unique laboratory, installed at Stanford University, began experiments on the flow of hot brines, hot water, and steam through typical reservoir rocks to evaluate the effects of aquifer stimulation techniques.

In energy resources, attention was placed on coal, the most abundant U.S. fossil energy resource. Expertise in the extraction, conversion, and utilization of coal was brought together at a workshop on advanced coal technology. The results included definition of gaps in the data base and fundamental information and recommendations of research to be undertaken. Very high yields of benzene were obtained in experiments on high-temperature, short contact time hydrogenation of coal. Toluene and xylene, constituents of high-octane gasoline, were observed as products in the process, pointing to the possibility of converting coal economically to more usable fuels.

A major laboratory for fluidized bed research applicable to coal conversion technology was established at City College of New York. Experiments conducted in the facility showed that fast fluidized bed technology may significantly improve coal gasification reactions over slow bed processes.

In energy conversion and storage, research results during fiscal year 1974 point to significant opportunities for improving the efficiency of the utilization of the world's scarce energy and fuel resources. Progress was achieved in defining new battery concepts, waste heat management, improvements in topping and bottoming cycles for central power station operations, and combined-cycle power station operations.

Testing of a full-scale welded cell for a high-temperature lithium-sulfur battery was completed at the Argonne National Laboratory. The Ford Motor Co., working with the University of Utah and the Rensselaer Polytechnic Institute, made important progress in solving the problems of failure of the alumina solid electrolyte of the sodium-sulfur battery. A working laboratory model was produced of a battery system based on lead and lead oxide. This system is pointed toward the "burning" of coal in an electrolyte that will retain all ash and sulfur impurities, with efficiencies about the same as those of present powerplants.

Shakedown operation began at Oak Ridge National Laboratory of a potassium boiler-furnace module, using water as the working fluid, which would increase the overall efficiency in conventional turbines from 40 percent to more than 50 percent, thus reducing waste heat and fuel consumption.

In energy and fuel transportation, Brookhaven National Laboratory, using superconducting tapes of an alloy of three parts niobium and one part tin (Nb_3Sn) reduced by a factor of five the energy losses in alternating current transmission below those measured previously using such tapes. The achievement of this milestone removes a major impediment to the use of this alloy, which is superconducting at relatively high temperatures.

During fiscal year 1974, the Foundation initiated a program directed toward the combustion and material problems in automobile engines. Under grants to universities, investigators are examining alternative fuels, emulsified fuels, and the stratified charge approach. The new program stimulated broadened discussions among combustion experts of the automotive manufacturers and the universities. The potential for contributions in this area is indicated by the fact that almost 25 percent of the U.S. energy consumption is by the automobile.

Energy Technology Assessments

To give policymakers a better understanding of energy resources, several assessments of energy technologies were initiated. The Futures Group in Glastonbury, Conn., began a technology assessment of geothermal energy resource development. Terrestrial solar energy technology was the subject of an assessment undertaken by Arthur D. Little, Inc., of Cambridge, Mass. These projects were directed not only toward public policy analysis and advice, but also to providing capability for more sophisticated analyses of complex technological options.

Investigation of the implications of alternative methods and strategies of conserving energy was initiated by Braddock, Dunn, & McDonald of Vienna, Va. Alternative physical technologies are being considered, as impacted by regulation, taxes, incentives, subsidies, or other strategies and methods. The study explores not only the efficacy of the various strategies, but also their derivative downstream impacts on work, leisure, life styles, and institutions.

The impacts of using hydrogen gas or liquid as a major fuel intermediary were studied by the Stanford Research Institute. One of the interim conclusions is that there is little or no feasibility of using hydrogen as an automotive or other "portable" fuel because of the very large impact on the technological infrastructure. In other words, society would have to change so much to utilize hydrogen extensively that it is virtually precluded from portable uses for some time to come.

Environmental Effects of Energy

A new program initiated during fiscal year 1974, Environmental Effects of Energy, focuses on studies leading to environmentally acceptable policies on energy production. Significant problems under examination relate to the environmental impacts of fuel sources extraction, processing, energy generation, and consumption, with special attention to land use and water resources planning to minimize the economic, social, political, aesthetic, and ecological disruption. The program, coordinated with other Federal agencies concerned with this problem, covers pollutant analysis, transport and fates, ecological effects and control, regional issues, and the impacts of production of coal, shale oil, petroleum, gas, and solar and geothermal energy.

Results during fiscal year 1974 of previously initiated work in this area include:

- Findings by researchers at the University of New Mexico that the accumulation of mercury in large predatory fish had reached the public health danger level and might be increased further if a coal-fired plant under construction were not properly designed.
- Completion of an assessment of the environmental effects of oil shale production.
- Use of an air pollution prediction model, produced by NSF-supported researchers, by the San Francisco Bay Area Pollution Control District to guide local and regional decisionmaking.

Social Systems Impact of Energy

Information on public responses to the energy shortage that became acute in the winter of 1973-74 was obtained with NSF support in connection with the Continuous National Survey, conducted by the National Opinion Research Center. Results of interviews with national samples of the U.S. population showed that a large majority of the public reacted to the energy shortage by curtailing uses of electricity and automobiles. Substantial major-

S.F. BAY AREA AIR POLLUTION
STUDY PROJECT (HIGH ALTITUDE PHOTO)

In a project leading to environmentally acceptable policies on energy production, high altitude photos of the San Francisco Bay area are used to study the polution of the area and to help develop an air pollution prediction model.

ities felt that the energy shortage would affect them over the ensuing 6 months. About 40 percent felt that the shortage would affect them seriously over the next 5 years.

Reductions in driving were largely in the use of cars for recreation and pleasure; the use of automobiles for trips to work remained high with very little evidence of major attempts at carpooling or other arrangements.

Intergovernmental Impact of Energy

The National Governors' Conference undertook in fiscal year 1974 the Governors' Energy Project to establish and implement a mechanism to coordinate State efforts in energy with relationship to each other and to the Federal Government. The project is supported jointly by the Department of the Interior, the Atomic Energy Commission, and the NSF, with the Foundation supplying the leadership within the Federal Government. During its initial months, the project made major contributions to the energy-related amendments to the Federal Clean Air Act, to fuel allocation formula regulations, and to the nationwide automotive speed limit regulation.

Significant research reports published during the year included assessment of the implications for State governments of the Atomic Energy Commission's Plowshare program to utilize underground nuclear explosions for civil purposes. The research was performed by the Western Interstate Nuclear Board.

In Minnesota, NSF-supported research resulted in assessment of alternative methods of energy utility taxation, in the development of State legislation to implement the findings, and in studies of the economic and environmental implications of proposed mandatory bottle deposit legislation.

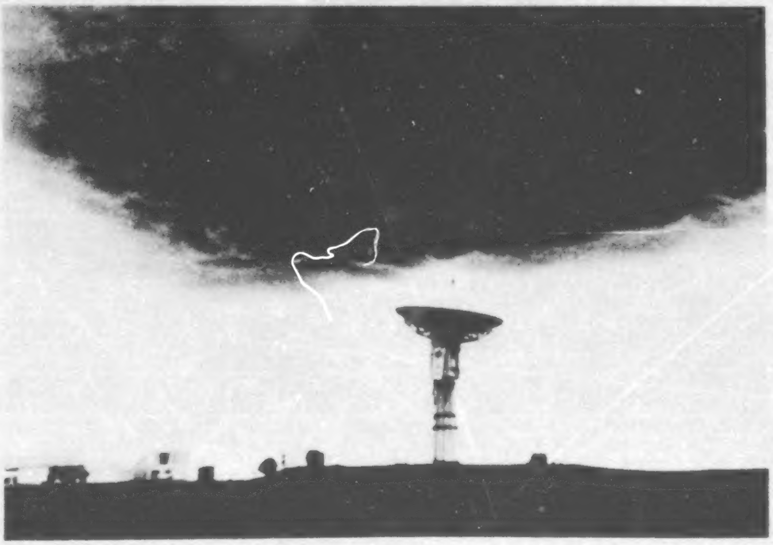
ENVIRONMENT

Threats to the Natural Environment and Environmental Management

Changes in natural environments, some of them detrimental to presently perceived values, were studied and documented by several programs supported by the Environmental Systems and Resources Program. The environmental alterations were nearly all brought about by human activities. Possible control of the changes by human actions was also examined.

The National Hail Research Experiment during fiscal year 1974 successfully completed the second of five planned field sessions. During the first two summers there were 27 hail days, of which 14 were seeded

NATIONAL HAIL RESEARCH EXPERIMENT 28.5 FOOT 10 CM RADAR ANTENNA



A 10-centimeter radar antenna monitors meteorological developments during the National Hail Research Experiment.

events that were systematically studied. In addition, there were more than 100 penetrations of hailstorm cores with armored T-28 aircraft, which yielded important information about the behavior and composition of storm updrafts. This knowledge will be utilized in subsequent field seasons and in ultimately devising better ways to suppress hail.

The first comprehensive economic analysis of hail loss on regional, State, and national scales to give good estimates of the magnitude of loss in geographic and time dimensions was completed by the Illinois State Water Survey. The information was transmitted to State and Federal agencies supporting hail and agricultural research and to hail insurance companies for assessing losses and for rate-setting decisions. Policy alternatives on the legal aspects of weather modification were developed at Southern Methodist University and given to Federal, State, and local government agencies for such uses as the formulation of weather modification legislation.

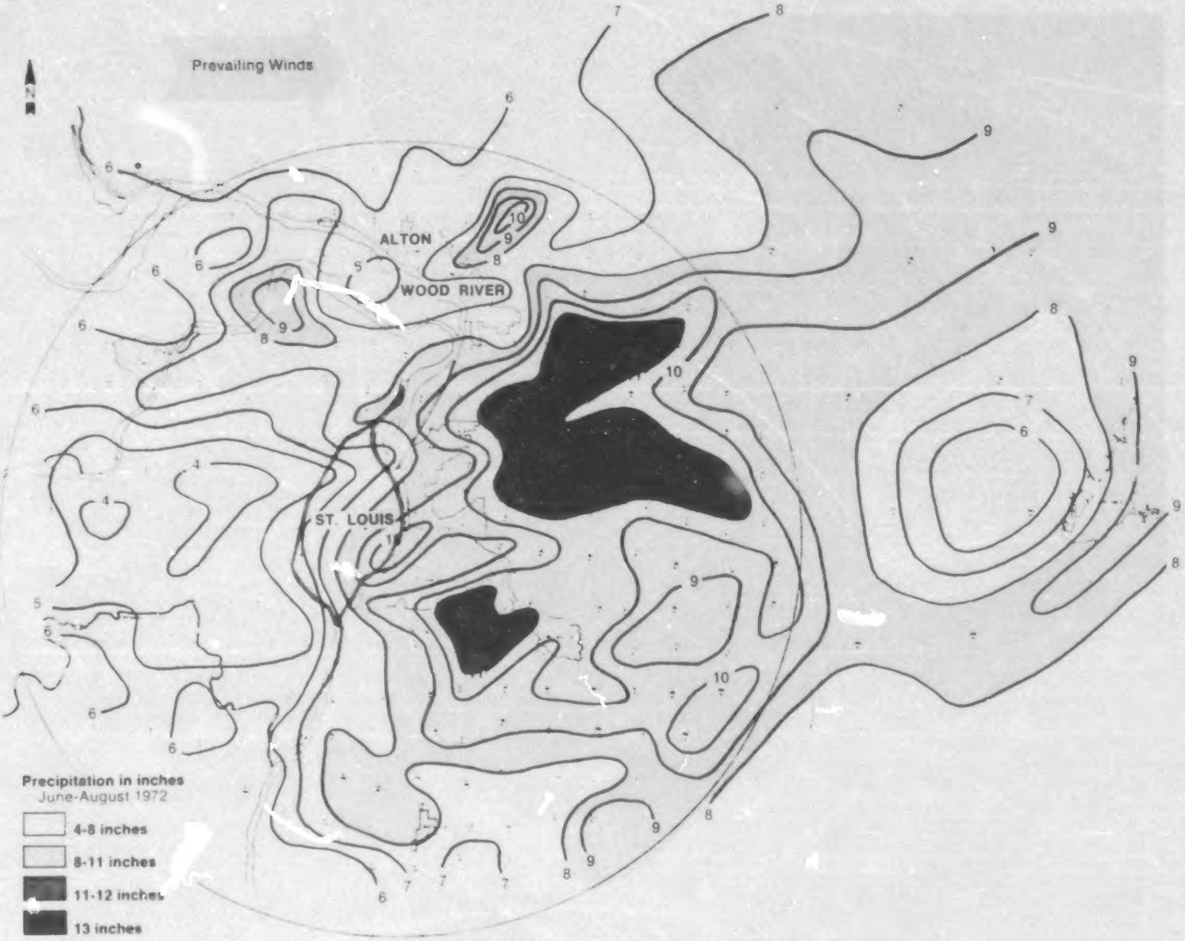
Rainfall and other weather phenomena in the St. Louis urban area were studied by a group of researchers from various universities and organizations during the summers of 1971-72. Researchers found an increase of 20 to 30 percent in precipitation downwind of the area. Showers over and downwind of the city were distinctly bigger, longer lasting, and greater rain producers than those that did not cross city areas. These factors are important considerations to urban planners in designing runoff channels, waste water facilities, and homesite codes.

As a result of research at the University of Missouri at Rolla, the AMAX Corp. decided to build a new 400-foot smelter stack (double its present height) at its lead smelter to disperse emissions more effectively in the New Lead Belt of Missouri. Consultation and sharing of data between the industry-operating superintendents, the university team, State regulating agencies, and U.S. Forest Service personnel led to agreement on additional necessary operational improvements in the Missouri Lead Belt. The success of this university-State-Federal relationship resulted in a decision by the British Zuckerman Commission to use this program as a base for England's action in developing the lead ore reserves in that country's national parks.

Information on dispersal of lead in automotive emissions and a detailed chemical analysis of automotive exhausts for specific lead compounds, performed at the Colorado State University, provided data of value to the Colorado Air Pollution Control Commission, the Colorado Governor's Science Advisory Committee, and the U.S. Environmental Protection Agency. An associated study at the University of Illinois illuminated the relationship of highway development and lead pollution in the vicinity of rights-of-ways and in nearby watersheds. Still another report, from a project at the University of California, Los Angeles, indicated that atmospheric lead contributes about 30 percent of the total lead intake of a person living in an urban environment with an atmospheric lead concentration of 2 micrograms per cubic meter.

Effects of various air pollution control programs on the emission patterns of the Chicago area, and the benefits and costs of alternative transportation control strategies that may be used to reduce air pollution, helped the Illinois Environmental Protection Agency to evaluate several policy options relevant to energy and transportation.

Research at the University of Washington showed that mercury



A precipitation map of the St. Louis area, based on measurements of rainfall taken during field operations June through August 1972, shows increased precipitation downwind of the metropolitan area.

levels in bottom sediments of Bellingham Bay have been diminishing rapidly since a local plant reduced its mercury discharge in mid-1970. A loss of about 50 percent of the mercury from estuarine sediments in 18 months is a strong indication that dredging of the bay need not be undertaken, with considerable economic relief to industry and cost savings to public agencies.

Environmental management studies matured with significant payoffs in fiscal year 1974. As examples, research by the University of Texas on bay and estuarine management provided direct input for enactment of three Texas coastal laws covering sand dune protection, administration of navigation districts, and coastal zone management. Colorado State University devised a range management model to aid the Soil Conservation Service and county agents in developing farm and ranch management plans for greater efficiency in livestock and crop production. Research results at the Hawaiian Environmental Simulation Laboratory, University of Hawaii, enabled the Hawaiian Department of Accounting and General Services to simulate the environmental consequences of selecting sites for State construction projects.

COASTAL MARSH DREDGING ACTIVITIES (GULF OF MEXICO)

Coastal marsh dredging activities along the Gulf of Mexico are under study as part of research by the University of Texas on bay and estuarine management.

Threats to the Manmade Environment

Research on threats to the manmade environment focused in fiscal year 1974 on earthquake engineering and fire research. As part of this effort, common features for diminishing the hazards due to earthquakes, fires, floods, hurricanes, and other extreme meteorological events were identified. The NSF project on Assessment of Research in Natural Hazards, at the Institute of Behavioral Science, University of Colorado, completed a social scientific description of several basic alternative methods that can lessen the impact of various natural phenomena upon man. In addition to examinations of 15 types of hazards, the investigators prepared working papers on land use management, warning, relief and rehabilitation, insurance, and distributional effects of alternative public policies as methods of mitigating disaster effects.

The Earthquake Engineering Program develops methods that allow decisionmakers to control the consequences of earthquake occurrences. Research projects are under way to find economically feasible design and construction methods for building earthquake-resistant structures of all types. Also, procedures are being determined for integrating information on seismic risk with processes of land use planning. The social and economic consequences of individual and community decisions on earthquake-related issues are being studied and results are presented in forms that can be used by the potentially affected communities to control their vulnerability to earthquakes.

The Seismological Field Survey maintains more than 1,000 earthquake strong-motion instruments, the majority of which are in California. These instruments measure the motion of ground and structures when they are subjected to earthquake shocks. With support from several Federal, State, county, and city agencies, progress was made during fiscal year 1974 in expanding this survey into a National Strong Motion Network. With NSF support, several strong-motion instruments were placed in upstate New York by Columbia University. On July 31 and August 3, 1973, the first strong-motion records were made for earthquakes east of the Rocky Mountains. This is a first step in obtaining the data set ultimately required to understand properly the extent of the earthquake engineering design applicable to eastern areas.

The NSF Fire Research Program in fiscal year 1974 supported research that developed understanding of the mechanisms of fire ignition, spreading, and extinguishment. Data were sufficient for significant improvements in fire safety in homes and urban areas, including tall structures with special problems. Studies included the modeling of fire processes, effectiveness of fire fighting systems, and the deleterious effects of smoke.

A multidisciplinary project at the University of California, Berkeley, on Fire Safety in Urban Housing led to several very important accomplishments of special interest to the Department of Housing and Urban Development. One of these provided fire safety criteria for single-family residential units, which the Department is incorporating into its Minimum Property Standards for housing. Experience has shown that a flammability test currently specified by the American Society for Testing Materials is unreliable for some plastic materials. Work at the University of California on a new test of fire in a room corner can be a promising complement to or replacement of present tests for the establishment of fire safety of residential units.

In a large-scale, interdisciplinary project at the University of Utah concerned with the toxicological and physiological effects of smoke from polymeric materials, a combustion chamber was modified to permit the measurement of the optical density of smoke. A computerized analytical system developed in that project permits rapid and accurate determination of the different chemicals in smoke.

At the Johns Hopkins University Applied Physics Laboratory a display case of tactics of the fire ground command and control system was completed with the cooperation of the Hillandale, Md., Volunteer Fire Department. An advanced model which couples a microfiche reader to the tactics case was also evaluated as a prototype system by the College Park Fire Department.

PRODUCTIVITY

Public Sector Productivity

The fiscal year 1974 priorities of the Social Systems and Human Resources Program were on the organization of service delivery in metropolitan areas, decision-related studies of local government management, the use of technology in local government organizations, and the design of programs to use telecommunications in delivering social services.

In the area of State and municipal finance, NSF-supported work at the University of Oregon carried out a detailed analysis of the current system of issuing municipal bonds with particular attention to the calculation of interest rates. The research showed that through improvements in the calculation of interest rates, it would be possible for governments to save substantial amounts of money by calculating interest rates that took into account the time value of money.

Since general revenue sharing is an important innovation in Federal-State-municipal relations, a research program was begun in which awards were made for a national survey of the attitudes of State and local government officials towards revenue sharing, for interviews with a sample of the general population to provide information on the degree to which local government officials' views of general revenue sharing corresponded to the views of residents of the same areas, and for the preparation of computer software programs to be used in the analyses of the effectiveness of general revenue sharing.

Under a grant to The Futures Group, a monograph was published detailing the social and economic aspects of what is known about legalized gambling. This issue is of particular current importance because a number of States have made provisions for lotteries and other States are considering such legislation. The analyses suggested that:

- Lotteries and off-track betting (OTB) are not likely to be significant sources of government revenue in relation to total revenues.

- Lottery expenditures are a small part of the players' budgets, and participants do not devote significant time or energy to playing the lottery. There probably are not meaningful economic effects on the players or their families.

- State lotteries and OTB are not likely to affect adversely the personal, familial, or work situations of the average bettor.

- Lotteries and OTB have not significantly reduced the total volume of illegal gambling, and hence do not appear to have reduced the potential for corruption of public officials nor freed law enforcement resources from antigambling law enforcement.

- Federal taxation of gambling winnings inhibits efforts of the States to compete with tax-free illegal gambling. Federal restrictions on lottery and OTB promotions are less of an inhibiting factor.

- Various forms of gambling can substitute for one another, and broad legalization of gambling may lead to saturation of the gambling market.

Research conducted at the University of Georgia on the effects of population distribution showed that the historical pattern of massive outmigration from the South to the North and West that had been characteristic of the United States in earlier decades no longer existed in the decade 1960-1970. In that period, the South became a net importer of white population. However, the outmigration of blacks from the South persisted at relatively high levels over the 1960-1970 decade. The research emphasizes the implications of population redistribution for governments that must provide services to growing or declining populations.

Results from research concerned with improving the delivery of urban services included:

- An analysis of the efficiency and effectiveness of the treatment of accident victims in Boston, using techniques that can be applied in other cities (MIT).

- The development of a system to evaluate the effectiveness of sanitation services in New York City (State University of New York at Stony Brook).

- Techniques for ensuring the security and safety of residential units by developing and testing alternative designs for the use of space (Center for Residential Security Design).

- The development of computer modeling techniques for more accurate forecasts of manpower needs (Ohio State University).

- An analysis of how the benefits and costs of tax systems and service delivery systems are distributed in Washington, D.C., Standard Metropolitan Statistical Area (The Urban Institute).

Private Sector Productivity

Several programs are directed at improving productivity in the private sector: enzyme technology, extractive metallurgy, excavation technology, instrumentation technology, and industrial automation.

The Enzyme Technology Program is working to increase national productivity by application of enzymes in new and improved chemical processes. At the Massachusetts Institute of Technology, an interdisciplinary group of chemists and genetic scientists took five amino acids, two enzyme fractions, and a cofactor and produced, in a two-step enzymatic reaction sequence, 1/2 gram of Gramiciden-S. The ability to produce such complex organic molecules with enzymes outside a living cell should make it possible to introduce reactants into a system which could not penetrate a cell and thus produce modified molecules not found in nature.

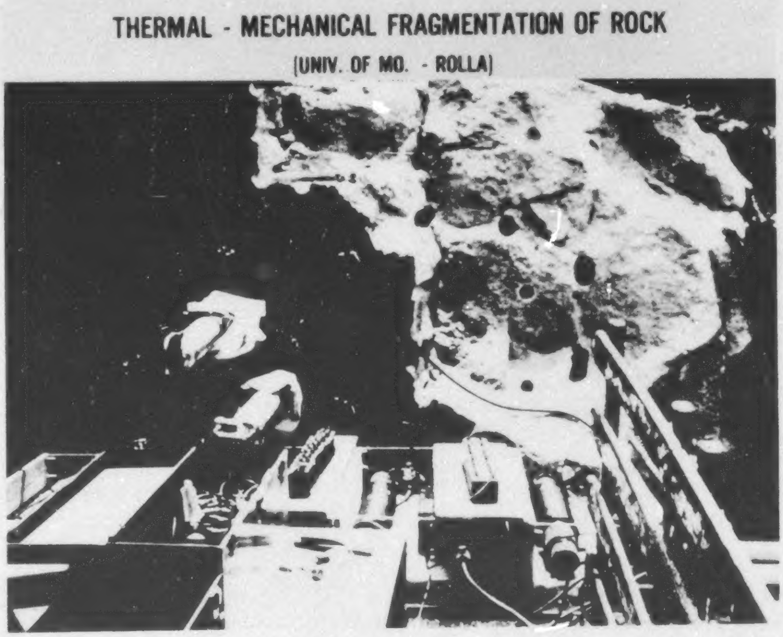
Research supported at Iowa State University used a two-step enzymatic reaction sequence to produce a mixture of glucose and fructose (invert sugar) from cornstarch. The sugar mixture can be used conveniently as syrup and provides a productive use of the Nation's great resource of corn as an alternative to sugar imports.

A group of engineers at the University of Virginia used enzyme or electrochemical methods to reduce the transmission of air- and water-borne virus diseases in public places such as hospitals, schools, or theaters. An ordinary air filter with a particle residence time of about 1 second, and with the enzyme ribonuclease immobilized on the glass fibers kills about 99.9 percent of the viruses passing through. Tests showed that the enzyme is stable for at least 100 days and is effective against eight types of viruses, including those involved in the common cold and the London and Hong Kong flu.

In the Extractive Metallurgy Program, the magnetic separation research at the National Magnet Laboratory, Massachusetts Institute of Technology, led to testing of a full-scale device for economically recovering iron from semi-taconite ore. Since there are huge deposits of this lower grade ore in the United States, a more productive process of recovering iron from it could significantly affect dependence on imports. The Hanna Mining Company began studies pointed toward proof-of-concept experiments.

The Excavation Technology Program emphasizes methods for increasing excavation rates and reducing the cost of subsurface excavation. Research supported at Martin Marietta enhanced drilling rates by controlling the chemical environments at the drill bit-rock interface. A series of hardness tests were run on quartz with the surface wet with various alcohols. With dilute alcohols such as heptanol and decanol, it was found that when the surface charge is reduced to zero, the hardness is increased to a maximum. In either of those alcohol environments, the drilling rates are 12 to 14 times faster than those in water environments.

Considerable progress was made on thermal fragmentation of rock at the University of Missouri at Rolla. In this technique, a series of holes are drilled to a prescribed depth and pattern. Electrodes are inserted in the



In studies of thermal-mechanical fragmentation of rock at the University of Missouri at Rolla, holes are drilled in the rock, electrodes are inserted, and the rock is rapidly heated until it fragments. This method results in removal of carefully predetermined sections of rock.

holes and the rock rapidly heated. Proper control can result in removal of carefully predetermined sections of rock. Precise fracturing is faster and more accurate than conventional drilling and blasting, and therefore reduces cost.

The Instrumentation Technology Program supports efforts to apply new instrumentation concepts for providing increased functional capability, greater sensitivity, broader coverage, and more rapid response at reduced cost. Projects are under way in use of highly ionizing radiation for cancer therapy and application of new instrumentation concepts to the general diagnosis and treatment of disease. Also, superconducting technology is being used for medical instruments, and work is under way on radiographic and radioisotopic imaging, ultrasonic diagnostic instruments, and other innovative instrumentation applications in industrial processes.

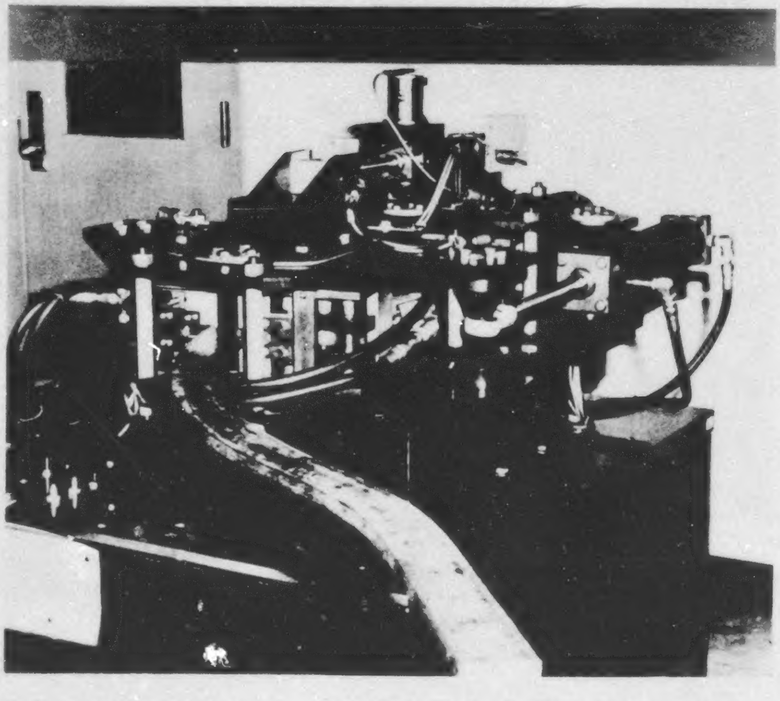
The MIT National Magnet Laboratory completed a device using a superconducting magnet to maneuver a magnetic catheter through the arterial system into remote areas such as the brain. The Massachusetts General Hospital undertook development of techniques for its use and secured the necessary clearances for clinical trials.

The Industrial Automation Program works on methods to stimulate the evolution of key segments of U.S. industry to use technologically advanced systems. Projects encourage research that addresses major problems in manufacturing and service areas, and emphasis is placed on solving problems that have a significant impact on productivity. Key segments of American industry are encouraged in strengthening their science base to complement their already strong experience-based system, and rekindle research involvement so that stronger relationships between American universities and industry in major industrial problem areas are established.

Research at the Charles S. Draper Laboratory at MIT delineated the first systematic analysis and problem definition of industrial assembly and the research issues associated with a new class of advanced assembler systems, organized about sensor arrays for measuring forces involved in assembly. A conceptual breakthrough was the breakdown and categorization of assembly operations into three basic types of motion—gross, interface, and fine. This provides a framework for relating past and future work and allows a concentration on the heart of the assembly problem—fine motion.

Research at Case Western Reserve led to a significant advance in the technology of making ship frames. The existing bending operation is a machine-assisted manual procedure using hot steel. The Case Western group constructed a one-sixth-scale computer-controlled bending device. This device is hydraulically operated and uses cold steel. In operation the steel is bent slightly, the bending force is released, the steel springs back, and transducers measure the amount of the bend. The computer then compares the actual bend with the desired bend, and the operation is repeated until the correct bend is obtained. The project was coordinated with the Maritime Administration and the Naval Architects and Marine Engineers organization. A private company plans to build a full-scale bender for shipyard use.

At the University of Rochester, a university-industry team made progress in developing the knowledge base necessary to manufacture



Working under RANN's program to help improve productivity in the private sector, researchers at Case Western Reserve constructed a one-sixth-scale steel bending device that is controlled by computer and functions automatically. With this hydraulically operated mechanism, cold steel is gradually bent to desired forms for ship frames.

automated parts. Metal removal operations were represented in terms of a mathematical model that contains all the necessary descriptive information on parts. Work progressed in the design of an interactive graphics system embodying the model which can be used to generate blueprints and designs for the parts. The model can be useful in planning and controlling the operations necessary for automated manufacturing of parts.

Intergovernmental Science

The Intergovernmental Science Program (ISP), established in fiscal year 1970, links Federal, State, and local government through activities to improve the use of research and technology to solve State and local problems. These activities are catalytic in nature, utilizing seed funding to initiate and establish capabilities for efforts that can be evaluated and carried forward by others having operational responsibilities.

During fiscal year 1974, ISP focused on activities to develop institutional strength in State executive branches, State legislatures, and local government, and to utilize the experience residing in Federal laboratories to address needs of the civil sector.

Work to realize the potential of remote sensing moved forward with NSF support in California through a coordinating function undertaken by its Office of Science and Technology and in South Dakota when the Governor established a special office. The Hawaii State Center for Science Policy and Technology Assessment, established following earlier NSF support, played a major role in preparing a State report on issues of urgent concern regarding the utilization of resources in the neighboring sea areas. In Ohio, the State implemented planning efforts supported by NSF by creating a Development Center with a $1 million initial appropriation to develop centers of innovation in energy, medical services and technology, quality of work, and new business entrepreneurship.

With NSF support, the National Governor's Conference initiated the Governors' Energy Project described in the Energy section of this report.

Support for State legislative activities during fiscal year 1974 led to the institutionalization of the California Assembly Science and Technology Committee, the establishment of a position of Legislative Staff Scientist in Illinois, and the creation of an Action Council responsible for analysis of environmental and economic development policy for the Kentucky Legislative Research Commission. All three activities are now fully State funded.

The New York Assembly Science and Technology Staff with NSF support held a workshop attended by legislators and representatives of professional societies in science, technology, and public administration. Of the 37 pieces of proposed legislation recommended by the workshop, 20 bills passed the assembly and 8 ultimately became law. Also with NSF support, the Center for the Study of Science Policy at the Pennsylvania State University completed a fundamental study on the development of scientific and technological capability in State legislatures.

NSF is providing support, through the National Legislative Conference, to an agency serving the 7,600 legislators of the 50 States. The professional staff of the Conference's Committee on Science and Technology carried out projects to relate science and technology to policies of the States, to assess mechanisms in the Legislatures for doing so, to operate a clearinghouse for pertinent information, to examine technology transfer activities in the States, to survey relationships between Legislatures and land-grant colleges, and to improve contacts between State and Federal agencies in science and technology.

The Citizens Conference on State Legislatures during fiscal year 1974 initiated programs to enhance the development of State health policy and the legislative organizations needed to do this work, and to establish model legislative committee staffs in the area of drug abuse and alcoholism. The programs, which grew out of earlier efforts supported by the NSF in the establishment of its model committee staff program, are supported by grants of $2 million each from the Robert Wood Johnson Foundation and the Department of Health, Education, and Welfare.

Working with local government, a "Consortium for Technology Initiatives" was organized to bring together the Nation's 26 largest cities and 6 large urban counties to aggregate a market for research and technological solutions to urban needs.

The 2-year California Four Cities project, involving Anaheim, Fresno, Pasadena, and San Jose in experimental use of science and technology advisers with the support of NSF and NASA, was successfully completed, and plans were set in motion to expand it to a prototype statewide urban innovation network.

With NSF funds, the city of Tacoma, Wash., initiated a study to determine whether fire departmental costs might be converted from support by the property tax to a charge paid by all users, including tax-exempt institutions.

Local government research and technology achievements supported by NSF during fiscal year 1974 included assistance in transforming a sludge lagoon to an environmentally acceptable interstate highway, the development of an instrument enabling firefighters to "see through" smoke, a police heliport location model, a management-by-objectives manual, selection of a new and better fireboat for port patrol and safety, and methods for dealing with graffiti.

In the utilization of Federal laboratories, the Department of Defense

(DOD) issued a new policy, developed with NSF support, that allows for an expenditure of up to 3 percent of the professional man-years of any DOD laboratory on non-defense work if specified criteria are met. All projects must be funded by non-Defense agencies. Interagency funding of these efforts exceeded $12 million in fiscal year 1974 for projects in areas such as fire and safety, environment, health, law enforcement, transportation, instrumentation, and analysis and testing. The Department of Defense and the Foundation also institutionalized the experimental assignment of a representative of a Federal research and development laboratory with the Foundation, as a jointly funded assignment.

EXPLORATORY RESEARCH AND PROBLEM ASSESSMENT

The program of Exploratory Research and Problem Assessment initiates studies on selected problems that have potential for major national impact. Gaps in the spectrum of existing research relevant to national needs are approached through problem assessment and definition studies and through exploratory research projects.

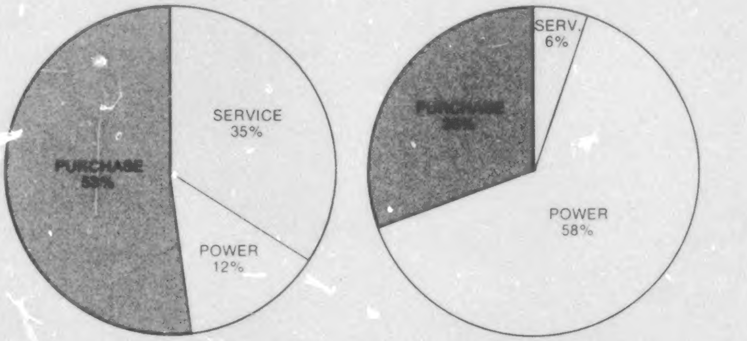
Considerable emphasis is placed on technology assessment, which may be defined as the systematic study of the effects on society that may occur when a technology is introduced, extended, or modified, with special emphasis on the impacts that are unintended, indirect, and delayed. In fiscal year 1974, work was begun on comprehensive, in-depth assessments of nine high-priority technologies, including those in the energy area reported earlier. In addition, studies were initiated on electronic funds transfer systems, biological pesticides, integrated hog farming, alternative work schedules, earthquake prediction, and metrication. In addition, the proceedings of a conference on preparing environmental impact statements were published and distributed to practitioners in Government and the private sector. The report contains commissioned papers on specific techniques, including computer modeling and cross-impact matrices for improving the perception of environmental consequences.

Another report, entitled *The Productivity of Servicing Consumer Durable Products*, prepared by the Center for Policy Alternatives at the Massachusetts Institute of Technology, was distributed to government officials, trade associations, electronics and appliance industries, and consumer organizations. The research team concluded that while service needs on appliances have diminished, service remains an important part of operating costs, and thus of the overall cost of the product. Another finding was that warranties have had a large effect in leading to greater reliability of appliances.

An interdisciplinary team of two lawyers and two engineers at Carnegie-Mellon University identified a number of serious defects in the form and substance of product liability litigation. These defects include inadequate preservation of physical evidence, insufficient determination of causation, and inadequate certification of experts. The report, *Product Liability: An Interaction of Law and Technology*, was published in the *Duquesne Law Review*.

A significant problem assessment was made of consumer information processing research in relation to public policy needs. Bill Wilkie of the Marketing Science Institute concluded that the field is underdeveloped and inadequate to meet the needs of public policy.

R. David Pittle, former principal investigator on an NSF project to improve consumer safety through innovative consumer education, was appointed a member of the Consumer Product Safety Commission.



* Based on the year 1972 and discounted to time of purchase

A study of the real cost of consumer appliances, done at MIT, shows that consumer appliances carry unrecognized costs in terms of service and power over their life cycle. Components of life-cycle costs of color television sets (left) show large differences in terms of service and power costs from those of refrigerators (right). [After *Consumer Appliances: The Real Cost*]

The project will be continued and completed by his colleagues at Carnegie-Mellon University.

In minority group problems, issues related to accountability in special revenue sharing/block grant programs were explored at a conference held at Stanford Research Institute. The proceedings were distributed to policymakers in Government and community organizations.

Research needs of rural blacks was the topic of a problem assessment project completed at Mary Holmes College, West Point, Miss. Among those needs identified through a survey and conference were studies of the values and aspirations of rural southern blacks.

At Navajo Community College, Tsaile, Navajo Nation, Ariz., a problem assessment was started to identify the problems facing the Navajo Nation with regard to industrial development and major research and policy issues associated with the management, utilization, and conservation of natural resources on Navajo lands.

Two problem definition studies were completed in technology-related international problems. Research priorities included international aspects of energy policy, environmental management, oceans policy, and technology transfer. Preliminary assessment was completed and major research and problem areas were identified on the changes in the status of women.

With NSF support, a research group at the Institute of Society, Ethics, and the Life Sciences, Hastings-on-Hudson, N.Y., published a book resulting from its investigation of the ethical, social, and legal issues involved in the applications of behavior control technologies. The book, *Operating on the Mind: The Psychosurgery Conflict*, includes guidelines for the regulation of psychosurgery.

RESEARCH UTILIZATION

The RANN Research Utilization Program works to assure that research is directed toward users and that the results are tested against their needs. An important step toward this goal was the issuance, during fiscal year 1974, of the NSF-RANN Guidelines for Preparation of Unsolicited Proposals. These guidelines specify the required details on utilization plans, which must include user group identification, user demand description, utilization process description, and a utilization budget.

Utilization activity progress during the year included the completion of proof of the concept of an environmental extension system patterned after the Agricultural Extension Service. The feasibility experiment was conducted in the States of Oklahoma, Colorado, and Tennessee, with the cooperation of State governments, universities, the Department of Agriculture, and the Environmental Protection Agency.

Some of the other research utilization results included:

- Substantial progress toward the development of a master plan of research pointed towards preserving and restoring the environmental values of the Lake Tahoe Basin under the direction of a California and Nevada bi-State agency.

- Initiation of activities by researchers at Iowa State University and representatives of corn syrup manufacturers to use NSF-supported research results on an enzyme process for converting cornstarch to sugar.

- Tests by the Tri-State Generation and Transmission Company of computer-controlled electric substation operational techniques resulting from research at the University of Missouri.

- Coordinated planning by the steel industry to evaluate and utilize Purdue University research results on automated steel processing.

- Initiation at Indiana University of preparation of a manual for industry on the characteristics of ores of 50 metals with respect to high-gradient magnetic separation and beneficiation techniques.

- Publication of a basic source document on technological transfer activities throughout the Federal Government.

- Establishment of a joint university-industry research group under the leadership of a North Carolina State University scientist to review the potential of high-energy radiation techniques in the textile industry.

- Initiation of an effort by the American Institute of Architects Research Corp. to develop a master plan for computer-based systems for building codes and their administration.

The Research Utilization Program also conducted extensive activities pointed toward broad dissemination of documented research results to users and potential users. During fiscal year 1974, a major symposium on RANN research results was attended by more than 1,500 persons from business and industry, government, national organizations, foreign embassies, and the research community. The proceedings of this symposium were published and distributed widely.

A RANN Document Center was established for the dissemination of research reports. The center, located in the Foundation's offices, is open to the user and research communities and the public. An initial bibliography of RANN energy research reports in this center was published.

Four films were produced covering the subjects of geothermal energy, solar heating experiments, efforts to reduce environmental pollution associated with lead mining and smelting, and automated ship frame bending.

A workshop on the results of research and industrial feasibility studies in solar heating and cooling was attended by more than 700 persons representing the construction industry; manufacturers; architects; banks; planners of new communities; Federal, State, and local governments; and the research community.

Science Education

Fiscal year 1974 marked the first full year of operation of the NSF Education Directorate's restructured program of Science Education Improvement activities. While earlier NSF education activities have had a marked effect on science education in the United States—and many countries abroad as well—some of the problems toward which they were directed, such as a general shortage of scientific research manpower, now have been reduced, to be replaced by others of growing importance. Certain of these problems have been identified as being relevant to the Foundation's mission and capabilities.

The changing nature of our society and its economy has created a need for a range of scientific and technical competencies well beyond those possessed by individuals whose academic preparation is primarily for pursuit of careers in basic research. The student body of the Nation's schools, colleges, and universities is much more varied now than in previous generations. Institutions must be responsive to a broader spectrum of student abilities, talents, and needs.

The increasing technology-based character of both the production and service sectors of the economy requires that all citizens, nonscientists as well as scientists, have an understanding of the impact of science and technology on their careers as well as their daily lives. The rate of change has become so rapid that obsolescence with respect to employment imposes a need for continuing education in many forms for many people. The increasing costs of education require research into and implementation of more effective kinds of organization and management structures and instructional methods at all levels of education. New ways must be found to bring the results of research and experimentation into direct, regular use in schools and colleges.

In recognition of these factors, the major objectives of the Foundation's fiscal year 1974 Science Education Improvement activities were to:

- Help assure the Nation of an appropriate variety, flexibility, quality, and amount of scientific and technological manpower with greater participation of minorities and women.

- Improve science education to: (1) meet the needs of a broader range of students; (2) increase substantially the number of persons who make effective use of the processes and results of science in their work and personal lives (whether or not they are engaged in scientific or technical occupations) and who understand public issues involving modern technologies; (3) develop and implement new instructional strategies and methodologies; and (4) disseminate the knowledge gained from research on the processes of learning and education.

- Find ways to increase the impact and effectiveness of the Foundation's Science Education Programs through research and problem assessment which can point to necessary future program directions.

Program activities were structured around four major themes:

- Improvement of education for careers in science

- Development of science literacy

- Increasing the effectiveness of educational processes

- Problem assessment and experimental projects.

Table 6
Science Education Improvement
Fiscal Year 1974
Summary of Obligations

Improvement of Education for Careers in Science	$28,676,587
Improvement of Education for Scientific Literacy	23,635,267
Increasing Effectiveness of Educational Processes	13,934,528
Problem Assessment and Experimental Projects	1,464,227
Total	$67,710,609

IMPROVEMENT OF EDUCATION FOR CAREERS IN SCIENCE

Program support activities in fiscal year 1974 were addressed not only to the problem of maintaining the quality of training in the traditional science disciplines, but also to the development of new, flexible instructional patterns leading to a wider variety of scientific and technical career options. Efforts supported in fiscal year 1974 included course material development and implementation at the secondary through continuing education levels, as well as some experimental models at undergraduate and higher levels. Another approach to curricular change was through the Student-Oriented Program, aimed at demonstrating the value of increased student research participation in the learning process. The Ethnic Minorities and Women in Science program was created to find ways to increase the disproportionately low number of people from these groups who form a portion of the Nation's scientific and technological manpower supply.

Secondary School Program

Since motivation toward a scientific career or one in a technological support area first becomes evident in most children during the adolescent years, it is essential to give attention to this phase of a student's development. Much of the support given by the Foundation in curriculum development in the 1960's was directed more toward the academically oriented, potential science student than toward the student with less specialized interests. Therefore, a relatively small portion of the NSF education allocation has been spent in this program for the past 3 years, with the major effort shifting to science literacy to compensate. However, funding was continued in fiscal year 1974 for the Biomedical Interdisciplinary Curriculum Project, which is designed for the potential biomedical technologist. Other current curriculum development projects contain significant career-oriented portions, usually as modules or units probing a subject in greater depth, which can be focused on the potential scientist.

Implementation activities are more fully described in the Science Literacy section of this report. In fiscal year 1974, 11 implementation projects supporting 610 secondary school teachers and resource personnel were devoted exclusively to advancing the student oriented toward an eventual career in science. These projects were involved principally in aiding school districts to introduce new mathematics curricula in their high schools through the provision of special training in the use of the new instructional materials and methods.

Alternatives in Higher Education

Through support of Alternatives in Higher Education, the Foundation's Education Directorate seeks to maintain existing strengths in college- and university-level science education while at the same time encouraging a closer matching of academic training with the broadened range of scientific functions and abilities needed in society today. Project support is directed towards encouraging a form of higher education that prepares a cadre of scientific manpower more flexible in their subject-matter usage than has been typical in the past, and better prepared to work in problem-related situations.

The 1974 program has focused on the following: development of course materials and experimentation with new modes of delivering science instruction; development of options to the traditional type of undergraduate and graduate degree programs; development of new and improved science research and technology; enhancement of the competence of college teachers in those interdisciplinary areas concerned with national needs and issues for which course materials and instructional modes may be introduced into the undergraduate curriculum; and use of new instructional scientific equipment to help colleges and universities improve the content and focus of their undergraduate courses.

Instructional Materials and Modes and Alternative Degree Programs

The three areas of special concentration in material and modes development in fiscal year 1974 have been projects to provide instructional materials in problem-related areas of special national need, the exploration of cooperative development and distribution systems, and the continuance of materials development for introductory and core science technology studies.

Virginia Polytechnic Institute, in cooperation with a number of electric power companies, is developing a series of learning modules to cover the principles of nuclear power engineering. These modules will extensively use computer modeling in simulation and will be tested and revised in conjunction with engineering departments at other academic institutions.

Work in several national curriculum projects continued toward the development of a large bank of instructional units in core science disciplines. Thus, the Computer and Laboratory-based Calculus (CALC) project at the

Education Development Center approaches college mathematics from intuitive and problem-solving examples drawn from many fields of interest. In biology, the minicourse development project directed by Samuel Postlethwait at Purdue is finishing its work on some 250 multimedia packages on core concepts in modern biology, and Project Biotech has begun its final phase of development of skill-oriented modules, emphasizing operational techniques.

The Tech-Physics project entered its final phase with grants to the American Institute of Physics, Florissant Valley Community College, the Technical Education Research Center, and the State University of New York at Binghamton. Some 20 modules are being developed in which physical principles are developed through the detailed examination of common pieces of equipment—an approach which is closely related to that of the CALC project.

Alternative Degree Programs have emphasized the exploration of curriculum prototypes which lead to a wider variety of career options. Highest priority is given to those projects in which there is a significant element of experimentation and a meaningful departure from traditional degree structures.

Support was continued into the final 2 years of an experimental program at Illinois Institute of Technology for a totally restructured undergraduate engineering program. Primary emphasis in this program is placed on the development of problem-solving abilities and the traditional curriculum of courses is replaced with a series of problems drawn from a spectrum of application areas to be solved by student teams. Students working on these problems develop a need to know specific information and skills; these are provided by a bank of several thousand self-instructional modules and a series of special-topic seminars.

Two projects initiated this year will develop nonresident master's degree programs which offer multidisciplinary, problem-solving curricula. A program at Carnegie-Mellon University in transportation is designed as an alternative to the traditional procedure of uninterrupted education through graduate school without benefit of intervening periods of employment or other nonacademic experiences. A somewhat similar program in format, but in the field of telecommunications, being developed at the University of Pennsylvania, stresses the educational benefits of cross-disciplinary work and internships with various governmental, commercial, and public interests.

A project was funded this year for the development of an innovative master's degree curriculum in art conservation. The University of Delaware is developing a broad-based master's degree program for museum conservators, in collaboration with the Winterthur Museum, and with joint funding from NSF and the National Endowment for the Arts. This program will couple the physical and analytical chemical techniques necessary for restoring and conserving art and other cultural objects with the requirements of a deep understanding of art history.

College Faculty Workshops

In addition to the course material development accomplished in the projects described above, practicing college teachers were involved in the development of modular instructional materials through the College Faculty Workshop Program. Selected college faculty contribute their talents as teachers and their knowledge of the requirements and capabilities of students to the work of research scholars in developing and testing curricular materials for undergraduate students of science. The initial group of workshops, supported in fiscal year 1974, are to develop curricular materials on topics in astrophysics, energy conversion, air pollution control, transnational policy issues, and the health sciences; to prepare computer-assisted instructional materials for courses in the physical and the social sciences; and to adapt instructional procedures for low-achieving or culturally deprived undergraduate students of science.

Faculty Fellowships in Science Applied to Societal Problems

In order to help 2- and 4-year college and university science teachers increase their competence in areas concerned with our Nation's societal problems and their possible solutions, the Foundation awarded 91 Faculty Fellowships in Science Applied to Societal Problems in fiscal year 1974. Awardees were selected from among 683 applicants for tenures ranging from 3 to 9 months. In addition to a salary-matching stipend, the Foundation provided the fellowship institution with an allowance to assist the institution in meeting tuition and other costs.

Faculty Research Participation

To encourage and assist teachers in reevaluating the relevance of their course material to the needs and requirements of students, opportunities are provided for college teachers to participate in the ongoing research activities of industrial laboratories and research institutes engaged in the application of scientific know-how to the solution of problems of national interest and concern. The 61 projects supported in fiscal year 1974 involved problems of engineering construction, storage, conversion, and use; food production; industrial waste, pollution, and environmental toxicants; development and production of new materials and resources; and aquatic ecology.

Instructional Scientific Equipment

This fiscal year, 373 awards were made to assist in implementing specific course and curriculum improvements through the acquisition, on a matching-fund basis, of necessary instructional equipment. Awards were made to both 2- and 4-year colleges; the majority of the awards were for equipment to improve curricula and teaching laboratories in the physical sciences.

Science and Engineering Technician Education

To assist in providing the trained technical personnel for research and technology, particularly in those areas in which manpower is needed to help solve contemporary national problems in fields of science and engineering, the Foundation in fiscal year 1974 initiated the Science and Engineering Technician Education Program. Four grants have been awarded for the development of new and improved prototype programs for technical support personnel. The grants share the following common features:

- Adaptation of, and addition to, nationally developed core science curriculum materials.
- Production of new modules in specialized technological areas.
- Exploration of new curriculum and program structures emphasizing adaptation to diverse student needs.
- Involvement and collaboration with other institutions in development and testing.

The projects at the University of Texas at San Antonio and the University of Wyoming are in the area of chemical technology, while that at the Junior College District of St. Louis concentrates on instrumentation and the preparation of general engineering technicians, and that at Oklahoma State is for electrical power technologists.

Continuing Education for Scientists and Engineers

Efforts are directed toward developing and demonstrating effective ways to continue the professional education of scientists and engineers in the nonacademic labor force. In the past the Foundation has supported several experimental approaches to continuing education in which universities have cooperated with local industries in offering specialized instruction to practicing scientists and engineers in the area. In this fiscal year, as another approach, the Foundation has funded a professional society to develop a prototype continuing education program. The American Chemical Society (ACS) is developing continuing education material in chemistry, designed to facilitate individual use and to accommodate to a short course format. Modes of instruction to be developed will include computer-assisted materials, color videocassettes augmented by audiocassettes, films, and printed materials. Tests devised by the Educational Testing Service will attempt to determine whether satisfactory mastery of the material is achieved, and field testing will be done within industry, Government agencies, and also by some local ACS chapters. An important element is to be the extensive documentation and appropriate software which will be made available to other professional societies that might wish to initiate similar programs.

Student-Oriented Programs

The three activities of the Student-Oriented Programs are directed toward science-talented students. In all three situations, the objectives are to foster increasing independence of the students, to identify future leaders, to conserve scientific talent, and to place upon students more responsibility for guiding their own learning.

Student Science Training

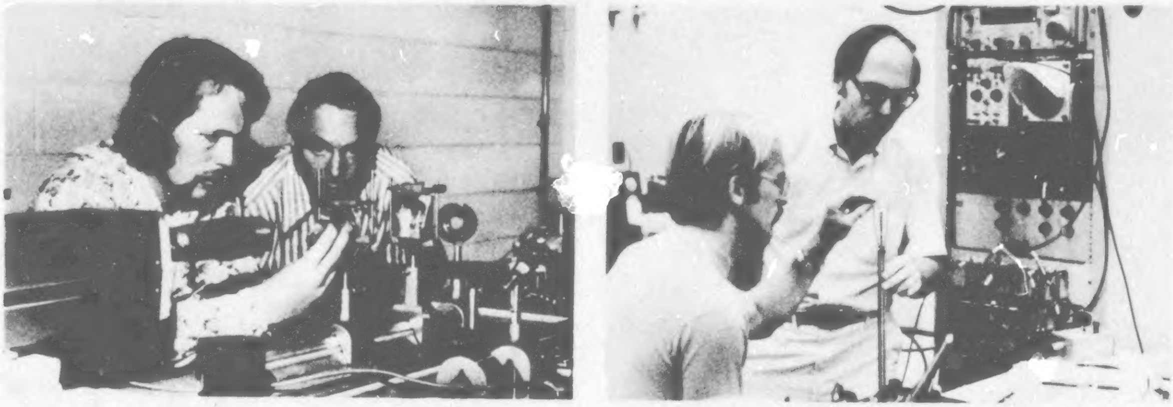
Through Student Science Training a limited number of advanced secondary school students receive special instruction in science and/or a period of participation in a college or university research project. Projects in Student Science Training for high-ability secondary school students may be directed to those students with conventional science training or to those whose backgrounds are limited by the facilities and instruction of their schools. Thirty-one of the 79 projects supported in 1974 were planned for this latter group. A special group of seven projects brought both high school teachers and students together in testing ways to adapt this type of format and experience as a regular feature of secondary school offerings. In all, some 3,500 student participants were involved.

Undergraduate Research Participation

Support provided through Undergraduate Research Participation allows undergraduates who have completed a substantial portion of their requirements in science to work full-time directly with the faculty members on research projects. In 1974 the projects in this master-apprentice program were restricted to those dealing with the energy problem or with the management and/or utilization of renewable natural resources. The 173 projects at 144 colleges and universities included 1,300 participants.

Student-Originated Studies

Through Student-Originated Studies (SOS), undergraduates or graduates, or combinations of the two, who organize their own groups, may obtain support to carry out their own research activities with minimal faculty supervision. Proposals considered by SOS are conceived and written by groups of students. Those groups whose proposals are successful then carry out and manage the projects proposed. Most are designed to provide data useful to local governmental agencies in planning or administering public programs. In 1974, 135 awards to 115



Under NSF's Undergraduate Research Participation Program, students and faculty work in close coordination. At left, Gary Froehlich, senior electrical engineering student at Texas Tech University, talks over his laser research project with his faculty adviser, Larry Burton. At right, California State University, Sacramento, physics professor Charles Newcomb works with undergraduate Al Young on ultrasonic measurements in superconductors.

colleges and universities supported the work of 1,200 students.

A survey of the impact of Student-Originated Studies projects on the teaching patterns of the host institutions is nearing completion. The contractor has presented an outline of his findings and a full report will be delivered early in fiscal year 1975.

Ethnic Minorities and Women

Minority Institutions Science Improvement

To capitalize on a unique national resource and to help provide equal educational opportunities, grants are made to colleges and universities serving ethnic minorities for upgrading these institutions and their course offerings. In fiscal year 1974, 26 grants were made to individual institutions, including 3 established to serve Native American students. In addition, two interinstitutional grants were made for support of activities to assist the faculties of minority institutions in more effectively developing, selecting, and using instructional media and strategies in the teaching of the sciences and mathematics; one of these projects will focus on the utilization of computer-based instructional systems.

In support of initiating scientific research by faculty members of ethnic minority institutions, 47 grants were made in fiscal year 1974 to scientists in 22 institutions.

Minorities in Science Studies and Experimental Projects

Five studies to identify and assess factors which are barriers to the participation of ethnic minorities in scientific careers were initiated in fiscal year 1974. Three of the studies deal with aspects of engineering education, including problems associated with attracting prospective engineering majors, the validation of admission standards, and the retention of ethnic minority students in engineering curricula. One study, at Wayne State University, will obtain data which will indicate the kind and relative influence of variables affecting the career choices of minority undergraduate and graduate students. Another study will examine the educational and psychological barriers influencing participation in science by minority students in the high schools of the greater Norfolk, Va., area. A unique exploratory study at Stanford University will investigate and compare curriculum variables and mathematics learning by "Chicano" and "Anglo" elementary and secondary school students.

In addition, 10 experimental projects were initiated this year to test promising solutions to the problems associated with increasing the number of ethnic minority group members in scientific and technological careers. Three of these experiments will explore ways of preparing otherwise highly qualified high school students to meet academic requirements for college entrance. Two of these three projects involve black Americans in urban high schools and one—at the University of North Dakota—will involve 20 American Indian high school students. Four projects will experiment with various ways in which colleges and universities could identify, counsel, and prepare minority students for science and engineering careers, and two other projects will evaluate and compare methods of increasing science career awareness among minority junior high and high school students.

Women in Science Studies and Experimental Projects

Twenty-three grants were awarded in fiscal year 1974 to 21 institutions for 13 problem assessment studies to identify and study those factors that affect the number of women in scientific and technological careers and for 10 experimental projects to test various ways to increase the number of women in science.

Eleven of the studies are designed to determine what factors influence women in making decisions about education and careers in science, mathematics, and engineering; one will be concerned with the effects of cooperative education experience on college women majoring in science and engineering; and one will attempt to measure the current extent of participation of women in their pre-college or freshman college years, and are designed to develop techniques or materials that can be used by many institutions.

Graduate Student Support

Graduate Student Support has as its primary objective to provide a reasonable and continuous flow of highly talented individuals into science careers. Other objectives are to strengthen the technical competence of scientific and engineering manpower, specifically to help meet the Nation's energy problems, and to improve the access of graduate students attending historically minority colleges and universities to careers in science and technology.

Graduate Fellowships

In fiscal year 1974, 525 new Graduate Fellowships were awarded to students in the sciences, mathematics, and engineering, with selection based upon ability. More than 5,700 students applied for these NSF Fellowships, and the awards represent a success ratio of slightly over 9 percent. Honorable mention—defined as status fully worthy of a fellowship had sufficient funds been available—was accorded to an additional 1,859 of the applicants.

Each of the fellowships was awarded for 3 years of graduate study to beginning graduate students. The fellowships may be used over a 5-year period, which permits students to fit into their education programs other valuable scientific and academic experiences. Each fellowship carries a stipend of $3,600 per year for full-time study, and an education allowance of $3,000 to the U.S. institution in lieu of tuition and fees.

Fellowship awards were in the following fields: 12 percent in mathematics, 12 percent in engineering, 20 percent in physical sciences, 28 percent in social sciences and psychology, and 28 percent in biological sciences. Twenty-eight percent of the fellowships were awarded to women this year, in a competition in which women constituted 29 percent of the applicant population. This represents a rise in the percentage of women making application for and receiving NSF graduate fellowships, and a greater balance between awards and applicants by sex. In fiscal year 1967, for example, 19.7 percent of the applicants for new fellowships were women, while only 11.1 percent of the awardees were women; in 1973, the percentage had risen to 27 percent women in the applicant population compared to 24.1 percent women awardees. This development over the past several years represents a twofold improvement—in overall numbers of women applicants and awardees and in the ratio between the two categories.

This year, due to the annualization of the Foundation's appropriations, a new fiscal arrangement has been initiated whereby all Fellows attending a given U.S. institution are supported through an annual Fellowship Support Grant to that institution pursuant to a Fellowship Support Agreement between the institution and the Foundation.

Traineeships

To help meet the Nation's future energy research needs, the Foundation also awarded grants to 39 institutions for a total of 172 Energy-Related Graduate (ERG) Traineeships, which provide 3 years

Table 7
Improvement of Education for Careers in Science
Fiscal Year 1974

	Number of Awards	Net Obligations
Improvement of Education for Careers in Science—Total	1,061	$28,676,587
Secondary School Program	17	1,517,084
Materials	6	1,123,084
Implementation	11	394,000
Student-Oriented Program	387	5,130,313
Secondary	79	1,374,976
Undergraduate Research Participation	173	2,021,961
Student-Originated Studies	135	1,733,376
Alternatives in Higher Education	432	10,706,855
Materials	38	3,441,122
Alternative Degrees	17	3,122,773
Technician Education	4	1,002,445
Undergraduate Instructional Equipment	373	3,140,515
Continuing Education and Professional Development	184	4,715,280
Faculty Workshops and Chautaugua	25	1,307,790
Science Faculty Fellowships	91	1,484,365
Faculty Research Participation	65	919,440
Continuing Education for Non-Academic Scientists and Engineers	3	1,003,685
Ethnic Minorities and Women in Science	41	6,607,055
Minority Institutions	28	6,001,835
Minorities and Women in Science Projects	13	605,220

[illegible] support for advanced studies leading to doctoral or masters' degrees. Each ERG Traineeship provides a stipend of $3,000 per year and a $3,000 per year allowance to the institution in lieu of tuition and fees. ERG Traineeships will focus on one of three significant research areas: coal oil shale, solar energy, or geothermal energy.

The Minority Institution Graduate Traineeship fiscal year 1974 program helped to improve the access of students attending minority colleges and universities to careers in science through the award of 30 traineeships to 7 such schools. Each award provides for 3 years of support. Appointments are made by the institutions to individuals enrolled in advanced degree programs in the sciences and engineering; emoluments are identical with those for the ERG Traineeships.

DEVELOPMENT OF SCIENCE LITERACY

The Education Directorate's fiscal year 1974 emphasis on science literacy recognized the importance of increasing attention being given to the problems of improving the general level of scientific literacy of a broader segment of the population.

The goal of the science literacy activity is to increase substantially the number of persons who are able to make use of the methodologies of science as well as the results of scientific discovery, in their work and personal lives, whether or not they are engaged in scientific or technical occupations.

As our society becomes more and more technologically oriented, more individuals are becoming engaged in activities or in making decisions that require a scientific or technical background, and there is an increasingly wide range of jobs at all levels for which science training is highly useful, if not essential.

Concurrently, the Nation desires to make the benefits of more education available to more of its citizens. Our schools are now accommodating almost the entire school-age population and are thus faced with an increasing diversity of talents, capabilities, and career aspirations. To meet the needs of these students a wider variety of teaching materials must be developed, including materials that can be matched to the learning abilities of both the theoretically inclined student who learns readily from the printed page and the more practically oriented student who learns best from "hands-on" materials and tangible models.

Elementary School Program

Materials and Instruction Development

In mathematics, four conference reports, available as a result of fiscal year 1973 activities, provided a partial reassessment of mathematics education in the country and pointed directions for the Foundation's next steps in attempting to attain mathematical competence among the Nation's students. In response to the major recommendations of these reports, a number of grants were made, all designed to study more closely the teaching and learning process. Two of these, one to Eugene Nichols at Florida State University, the other to George Springer at Indiana University, will provide for development of materials at the elementary school level that should overcome some of the difficulties recently encountered in using content from earlier development efforts along with a close study of children's performance in the new materials. The use of Teachers' Centers as reinforcement for the teaching process is being investigated at Southern Illinois University, the University of Denver, and the University of Wisconsin at Whitewater. Investigations of mathematical learning in children are being undertaken by Edward Begle, Stanford University; Joseph Scandura, Research for Better Schools, Inc.; Robert Davis, University of Illinois; Max Bell, University of Chicago; and Hassler Whitney, Institute for Advanced Studies, Princeton.

Additional funds were made available for the combined science-mathematics project *Unified Science and Mathematics for Elementary Schools* (USMES), directed by Earle Lomon of MIT, at the Education Development Center. This project is nearing the end of its development phase and moving rapidly into implementation. Another aspect of the elementary school program is illustrated by a grant to Antioch College for an impact assessment of the elementary social studies course, *Man: A Course of Study*.

Instructional Improvement Implementation

A major restructuring of implementation activities at the precollege level was accomplished in fiscal year 1974. Attention is now focused principally on bringing innovative curriculum materials into the classroom and orienting the educational staff of schools and school districts in the appropriate use of the materials they have chosen. Implementation grants are categorized as: (1) *orientation of educational leaders*—involving teams from selected regions to become thoroughly familiar with one or two of the major curriculum projects supported by NSF so that local training can be handled by members of these teams, and familiarizing education system decisionmakers with new curriculum developments to increase their understanding of their options for improvement of instruction in the sciences and in mathe-

Under the combined science-mathematics project of Unified Science and Mathematics for Elementary Schools (USMES), a fifth grader in his classroom is learning about the many difficulties encountered when attempting to control variables in tests that involve human subjects.

matics; (2) *school system-centered projects*—for school systems committed to full implementation of one of the new curricula in their classrooms, in collaboration with local colleges to strengthen the quality of teacher training; and (3) *teacher-centered projects*—to permit individual teachers who have leadership roles in their own schools or school systems to gain thorough background in one or two curricula so that they may try out the materials in their local situations prior to a commitment for widespread adoption.

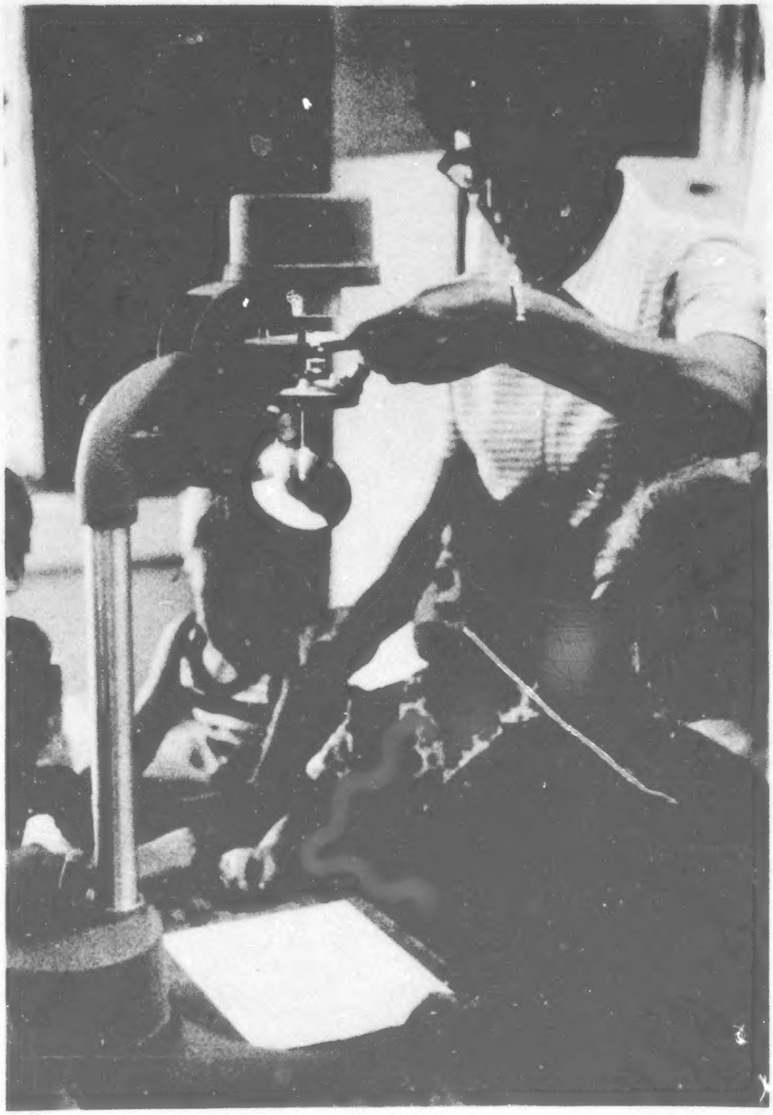
This year grants were awarded costing $5.9 million for elementary school implementation activities. A total of 17,587 teachers, supervisors, and other resource personnel in science and mathematics participated in 157 projects.

Secondary School Program

Materials and Instruction Development

The mathematics developments described under the Elementary School Program extend to the secondary school level. Grants to Boston University (Uri Haber-Schaim, Director) and the University of Oregon (Alan Hoffer, Director) will provide prototype materials. In addition, an analysis of mathematics achievement of secondary school students will be performed through the Conference Board of the Mathematical Sciences.

In the social sciences a behavioral science curriculum project has been initiated with an award to the American Psychological Association; the director is John Bare, of Carleton Col-



In NSF's Instructional Improvement Implementation project for elementary schools, attention is being focused on bringing innovative curriculum materials into the classroom and teaching the teachers how best to use them. In this case, a teacher is using a modern projector for showing brine shrimp.

lege. The development phase of the interdisciplinary course *Exploring Human Nature* is being terminated with this year's grant, and activities to aid implementation of the materials in schools and school systems have begun. The political science project *Comparing Political Experiences* was awarded additional funds for further development of instructional materials.

Interdisciplinary content characterizes current projects for materials development in the sciences. For example, the *Individualized Science Instructional System*, started in fiscal year 1973, received major funding this year for development of interdisciplinary modules for grades 10 to 12. The *Human Sciences Program* combines material from the biological and behavioral sciences for the middle school.

In order to aid in the dissemination of information about new instructional materials and methods, a new edition of the booklet *Course and Curriculum Improvement Projects* was published by the Foundation in fiscal year 1974. This booklet describes all of the significant projects, conferences, and studies dealing with course materials and instructional development since the inception of these activities in NSF. All pre-college grade levels are included in this publication.

Instructional Improvement Implementation

Restructured implementation activities funded under this program are the same as have been described above under the Elementary School Program. They were supported by 246 grants at a cost of $8.8 million. A total of 17,860 teachers and other resource personnel in secondary school science and mathematics were supported through these implementation projects to aid in bringing innovative curriculum materials into secondary school classrooms.

Table 8

Improvement of Education for Scientific Literacy
Fiscal Year 1974

	Number of Awards	Net Obligations
Improvement of Education for Scientific Literacy--Total	490	$23,635,267
Elementary School Program	169	7,940,900
Materials and Instruction Development	12	2,050,777
Instructional Improvement Implementation	157	5,890,123
Secondary School Program	271	13,482,110
Materials and Instruction Development	25	5,087,080
Instructional Improvement Implementation	246	8,395,030
Public Understanding of Science	50	2,212,257

PUBLIC UNDERSTANDING OF SCIENCE

The Foundation's long-standing commitment to enhancing public understanding of science and technology was strengthened in fiscal year 1974 with the support of 50 awards totaling $2.3 million. The primary objective of the Public Understanding of Science Program is to stimulate and encourage communication between scientists and the public on the role, substance, potential, and limitations of science and technology. Many projects supported in prior years reached the operational stage during fiscal year 1974, and with activities initiated during fiscal year 1974, a comprehensive public communications program is now in progress.

A most exciting development in public understanding of science during the past year was the premiere of the weekly NOVA science series televised nationally over the Public Broadcasting System. Produced by WGBH TV in Boston, in cooperation with the American Association for the Advancement of Science and the British Broadcasting Corporation, and supported by grants from the Foundation, the Corporation for Public Broadcasting, the Carnegie Corporation of New York, and Polaroid, the series was an innovative representation of the diverse world of science. Highly recognized by both the critics and the public, the 13 hour-long shows of the first season of NOVA dealt with such topics as the Colorado River, the search for life in outer space, the discovery of anesthesia, medical ethics, nuclear fusion research, and chimpanzee language. A second series of 22 shows is being produced for the 1974-75 television season.

Other television projects receiving support during fiscal year 1974 included a new public television series on economics, to be produced by Emmy-award winner David Prowitt in conjunction with The National Economists Club of Washington; the establishment at KPBS TV, San Diego, of an Office of Scientific Affairs; and the production at that station of several programs on science reflecting the interests of the San Diego community.

A number of regional and community public forums and conferences were supported in fiscal year 1974, many of which dealt with the interrelated subjects of energy, economics, and the environment. The American Association for the Advancement of Science continued to conduct a series of forums on energy in such communities as Chicago, San Diego, Tucson, and Portland, Me. A major series of environmental symposia was initiated at the Spokane International Exposition dealing with energy, agriculture, health, human settlements, population, and natural resource management. Other projects included three international symposia on global concerns with the environment; three northern California regional workshops on ecology, economics, and population growth; and in Tampa-St. Petersburg, Fla., a series of public

Washoe, the chimpanzee that learned to communicate with human beings with sign language, relaxes with a friend. A film of Washoe's language development was televised nationally as part of the weekly NOVA science series. [Photo by *Psychology Today*]

forums on population and growth, ecology, and energy.

Recognizing that museums are major communicators of information to the general public on science and technology, the program supported a number of exhibits and science demonstrations at museums around the country.

The process of communicating information on science to the public can, in large part, be only as effective as the capability of the communications media to deal with the complex issues and substance of science. Several projects were therefore supported, in cooperation with the journalistic profession, to improve the dialogue between scientists and journalists on topics of common interest and concern. The Council for the Advancement of Science Writing received support for the development of an educational program in the social sciences for leading journalists and editors. The program will provide updated information on the latest social science research findings and the process of research itself in the social sciences. Also supported was work by the School of Public Communications at Boston University on a comprehensive science journalism program at the graduate level, including provision for special intern assignments for young science journalists in various media outlets throughout the New England region, and the development of new educational courses in science journalism.

INCREASING EFFECTIVENESS OF EDUCATIONAL PROCESSES

While the question of cost-effectiveness is a consideration in all science education grants, the Foundation supports two major approaches to attaining a better balance between costs and educational productivity. One, Technological Innovation in Education, involves support of the application to the educational process of technological devices such as computers and television; the other, Educational Program Restructuring, focuses on a few major models of new approaches to the organization, management, and delivery of the content of education.

Technological Innovation in Education

Support has been provided for the development and field evaluation of technologies, techniques, and systems of instruction at all levels of education.

Two and one-half years ago, the Foundation committed itself to developing and field-testing two markedly different systems of computer-assisted instruction (CAI): the PLATO (Programmed Logic for Automatic Teaching Operations) system, designed to serve as an instructional computing utility for many hundreds of students at all levels of education, using radically innovative technology; and the TICCIT (Time-Shared Interactive Computer Controlled Information Television) system, designed to provide cost-effective CAI in mathematics and English to a cluster of roughly 100 community college students simultaneously, using minicomputers and television technology.

Good progress was made in both the PLATO and TICCIT projects during fiscal year 1974. Over 500 PLATO plasma panel student consoles have been installed, and it appears that the University of Illinois PLATO system will be serving nearly 1,000 consoles by 1976, the termination date for the field-tests which start in September of 1974. The system has been demonstrated extensively in the United States and abroad (including an extensive, invited demonstration in Moscow in 1973), and is widely regarded as a singular technological accomplishment. More than a dozen corporations have announced their intentions to market devices based upon the PLATO technology, and many universities have procured consoles for their own use.

The MITRE Corp., contractor for the TICCIT system and field-test, has built and installed a small system at Brigham Young University, where the CAI lessons are being prepared. A complete system was installed in the summer of 1974 at the TICCIT field-test sites in Arizona and Virginia. TICCIT has also attracted a good deal of interest and attention in the United States and abroad. The U.S. Navy has purchased one system, and may purchase a number of them if TICCIT's performance objectives are met. The first field use of TICCIT began in the fall of 1974, and will continue through the spring of 1976.

The TICCIT system, based as it is upon television technology, is also being considered as a delivery system for CAI and other interactive services into the home. During fiscal year 1974, MITRE completed an extensive study of the feasibility of such an undertaking and published a seven-volume report of the findings.

Support was also provided during fiscal year 1974 for especially promising *applications* of technology for educational purposes. For example, support was continued at several locations for the development and study of technologically based mathematical laboratories. Seymour Papert of MIT is applying principles from artificial intelligence theory, as well as computing technology and simulations, to instruction in mathematics, science, and music in an experimental elementary school. Thomas Dwyer of the University of Pittsburgh is developing a computer-based mathematics laboratory at the high-school level, and Alfred Bork of the University of California, Irvine, is studying the use of computer graphics for instruction in physics at the level of higher education.

Support was also provided during fiscal year 1974 for an extensive field-test of a system of interactive guidance and information (SIGI), to be conducted at several community colleges. This system promises to be a very useful tool not only for developing decisionmaking skills, but for studying students' decision-making processes as well. SIGI has been developed by Martin Katz of the Educational Testing Service, which is located in Princeton, N.J.

Educational Program Restructuring

Educational Program Restructuring aims to improve effectiveness and efficiency in science education through the design, development, and evaluation of major models encompassing the organization, management, delivery, and content of education. The program involves three principal areas of effort: preservice education of science teachers; State, regional, or urban systems of science education; and restructuring the undergraduate learning environment.

Pre-Service Teacher Education funds were devoted to continuing support of eight projects and initiation of evaluation activities at four major projects. Earlier evaluations have resulted in withholding the funds originally intended for the later stages of a few of the projects. Current evaluation, which has a more positive goal, aims at identifying and documenting the outstanding features of four of the projects to facilitate their transfer to other institutions. A "third party" evaluation (by persons other than project staff or NSF staff) has been completed that shows that the Purdue program enhances the intellectual growth of students. The Indiana University project, being implemented on some 30 other campuses, is the subject of an extensive third party evaluation.

During fiscal year 1974, the Foundation made 10 awards, totaling over $2.6 million, for systems projects. These are experimental projects which are attempting to find more effective means of coordination among all the agencies and institutions involved in pre-college science education within a specified region. Statewide projects were continued in Delaware, Oregon, and Oklahoma, with the general goals of improving the quality of science, mathematics, and earth science instruction, respectively. Two new projects, initiated in New York City and Lakewood, Colo., are working to develop models for improving science instruction at the middle-school level and for a computer-managed system for mathematics instruction, respectively. Third party evaluation of systems projects was begun with a grant to Western Michigan University to study the Delaware and Oregon projects.

A new program activity, Restructuring the Undergraduate Learning Environment, was initiated in fiscal year 1974 to encourage the development of major alternative institutional approaches to the style, organization, and content of undergraduate science. This activity supported five major projects totaling $2.1 million, and six design projects totaling $125,000. Two of the major projects are:

- Wesleyan University, Middletown, Conn., will establish its interdisciplinary College of Science in Society where students will enjoy a relatively unstructured opportunity to study science relative to its interaction with social institutions and personal values.

- Simon's Rock, Great Barrington, Mass., aims to become the Nation's first 4-year science baccalaureate degree-granting college designed for early entrance. After completion of the tenth grade, students may enter two broadly based interdisciplinary B.A. degree programs, premedical or environmental studies, with the expectation of graduation in 4 years.

Table 9

Increasing Effectiveness of Educational Processes
Fiscal Year 1974

	Number of Awards	FY 1974 Obligations
Increasing Effectiveness of Educational Processes—Total	78	$13,934,528
Technological Innovation in Education	41	7,431,568
Educational Program Restructuring	37	6,502,960
Pre Service Teacher Education	13	1,569,800
Systems Projects	10	2,462,500
Restructuring the Undergraduate Learning Environment	14	2,470,660

PROBLEM ASSESSMENT AND EXPERIMENTAL PROJECTS

The Problem Assessment and Experimental Projects program was begun in fiscal year 1974 to initiate studies and experimental projects on specifically identified problems in science education. The program's aims are: to gain knowledge about possible solutions to specific problems and to explore and develop techniques to alleviate those problems; to formalize an analytical and quantitative approach to program and project evaluation and planning, and to synthesize the results of problem assessment studies and experimental projects to provide guidelines for the creation of program alternatives responsive to projected as well as current needs of the science education community.

Problem areas in which staff-identified studies were initiated in fiscal year 1974 included:

- Current state and effectiveness of continuing education in the United States for nonacademic scientists and engineers,
- Barriers to the movement of women and ethnic minority group members into science and technology careers,
- Barriers to implementation of newly developed teaching materials and modes of instruction, and
- Effective means of moving new knowledge from the research community into undergraduate classrooms.

The staff-identified experimental projects areas included:

- Developing techniques to increase the number of ethnic minority group members and women in science, and
- Increasing availability of high school student project activity as an integral part of high school science programs.

In addition to the staff-identified study and experimental project activities, the program handled a variety of proposer-identified projects and studies. In the course of the year, the group considered 285 preliminary propo[illegible] 95 formal proposals, and recommended support of 69 activities. Among these was a major study of graduate education being carried out by the Council of Graduate Schools in the United States that will develop reliable instruments and procedures that can be used for evaluation and improvement of doctoral education. In another study, the American Institutes for Research will look at career guidance factors that affect the development of high school students' scientific potential to determine what high school students know about careers and what they need to know.

At the University of North Dakota, in a project partly funded by the Bureau of Reclamation, students proficient as pilots will be trained in the technical and scientific background needed for weather modification research. Brigham Young University will carry out a project in association with the Entomological Society of America to investigate barriers to teaching of new materials and modes of instruction in entomology.

The NSF Chautauqua-type short courses for college teachers received continued support in fiscal year 1974 through grants to 12 field centers for operating costs, and one additional grant was made to the American Association for the Advancement of Science for intercenter coordination.

Table 10

Problem Assessment and Experimental Projects
Fiscal Year 1974

	Number of Awards	FY 1974 Obligations
Problem Assessment and Experimental Projects—Total	29	$1,464,227

SCIENCE RESOURCES STUDIES

Science Resources Studies develop quantitative information on the Nation's scientific and technological resources. Appendix E includes a complete listing of such studies issued by the Foundation during the year. These were supplemented by numerous reports published by contractors. Highlights of the fiscal year 1974 program are outlined below.

Summary Reports

Two summary reports were released. One of these was the Foundation's annual report, *National Patterns of R&D Resources, 1953-1974*. The other involved a comprehensive analysis of the Nation's scientific and technological affairs and was presented in February in the National Science Board publication, *Science Indicators, 1972*. This report provides under one cover a summary of data compiled from science resources studies carried out primarily by the Foundation. Currently, efforts are being directed to improve existing indicators and develop a system of output measures including: quality of leadership indices based on literature citations, patent and economic performance relationships, indices of U.S. international positions in research underlying major new technologies, etc. These efforts will continue into fiscal year 1975.

Federal R&D Funding by Function

Since the contributions of research and development to the achievement of national goals is an important consideration, the Foundation has annually analyzed the Federal R&D budget in terms of major national functions. The latest report, *An Analysis of Federal R&D Funding by Function, FY 1969-74*, shows that Federal support for civilian R&D programs has risen steadily over the past 5 years at an average rate of 9.1 percent. During the fiscal year 1969-74 period, the civilian portion of the Federal R&D budget increased considerably faster than the space and defense components, although the latter two still represent about two-thirds of the estimated fiscal year 1974 Federal R&D expenditures. Funds specifically obligated for research and development in the area of energy development and conversion increased by nearly 14 percent between fiscal year 1973 and fiscal year 1974. The increased emphasis on civilian R&D funding is expected to continue into 1975.

Scientific and Engineering Manpower

In the manpower area important new NSF initiatives are beginning to produce results. The Manpower Characteristics System, which took the place of the National Register of Scientific and Technical Personnel, became operational in fiscal year 1974. Initial results from one of its three components, the Doctorate Roster of Scientists and Engineers (maintained for NSF by the National Research Council) were released. They showed that in 1973 there were about 230,000 doctorate scientists and engineers in the U.S. labor force. Among these, the unemployment rate was 1.2 percent in mid 1973. Survey results also showed that 6,000 of these doctoral scientists held postdoctoral appointments, 21,300 were women, and 15,200 were members of minority groups.

Another major step towards improved manpower information was the resumption of the annual survey of scientists and engineers employed by industry. This survey which was previously carried out by the Bureau of Labor Statistics had been inoperative since 1970. With industry employing about 70 percent of all scientists and engineers, it is important to have information on the types of employers, work activities, and other characteristics of this major part of the scientific work force. Development of a new survey was started with the Census Bureau, which will carry out this survey for NSF starting in fiscal year 1975.

One major new program in the manpower area was initiated by the Foundation as a direct result of the recently experienced energy crisis. With plans under way for major new energy initiatives by both the Federal Government and industry, it is important to identify possible bottlenecks in the implementation of these new energy thrusts. Scientific manpower could be one of these. Consequently, the Foundation started a program of study and analyses of information related to current and prospective utilization of scientific and engineering manpower in energy-related activities. Because of the urgent need for this information, initial fiscal year 1974 and fiscal year 1975 efforts involve rough, rapid surveys of industry and the Federal Government to determine the number and characteristics of scientists and engineers engaged in energy activities. At the same time, steps have been taken to develop large-scale, regular surveys which will provide similar information on a regular, annual basis so that in future years timely information will be available for important energy policy decisions.

Other Studies

Studies of academic science resources showed that Federal academic science obligations decreased by about 8 percent in constant dollars between academic years 1972 and 1973. In doctorate-granting institutions, full-time science and engineering graduate student enrollments dropped 3.3 percent between 1972 and 1973, while the number of federally supported, full-time graduate students fell to 52 percent of the fiscal year 1967 level.

While science resources studies concentrate on the accumulation and analysis of statistical information, they are also concerned with factors that influence the availability and utilization of resources. One important study culminating during fiscal year 1974 involved a Foundation-sponsored effort, *Chemistry in the Economy*, which was published in book form by the American Chemical Society (ACS). This study describes the accomplishments of chemistry in 20 of the Nation's largest industries and documents the way chemistry pervades the economy. The ACS made a number of recommendations dealing with various topics such as manpower studies, nonquantitative studies of science and society, education in chemistry, and industry interphase with other sectors of the economy.

SCIENCE POLICY STUDIES

Activities of the National Academy of Sciences and National Academy of Engineering

The National Science Foundation continued to support and utilize the advisory services of the National Academy of Sciences' Committee on Science and Public Policy (COSPUP). Among the committee's current activities are examination of the need for additional special studies in the areas of mathematics, the geophysical sciences, and astronomy. A study of criteria for determination of safety is being coordinated with the Consumer Protection Agency. In cooperation with the American Institute of Physics, COSPUP is working on an analysis of manpower information in astronomy and areas of physics related to astronomy. COSPUP also provides oversight to the joint U.S.-U.S.S.R. cooperative interchange in science policy. In cooperation with the Advanced Research Projects Agency, Department of Defense, the Foundation sponsored a comprehensive assessment of the field of materials science and engineering, undertaken by a committee of COSPUP, the Committee on the Survey of Materials Science and Engineering (COSMAT). The resulting report, *Materials and Man's Needs*, was published in December 1973. The report stresses national needs in this area and their implications for the organization and evolution of research and education in the field of materials. It attempts to advance further the effort made in earlier COSPUP reports to find ways of identifying priorities in a field of research.

Liaison also continued with the National Academy of Engineering's Committee on Public Engineering Policy (COPEP). The committee currently consists of 20 members, distinguished in engineering, research, or administration. COPEP identifies, develops, and undertakes studies of emerging issues of technology and related public policy and provides advice on the utilization of science and technology to achieve public purposes. Two major tasks undertaken this year were a study of Federal management of technology utilization programs and preparation of a report on the uses and limitations of technology assessment. Both of these are expected to be released in the near future.

Other Policy Activities

In April 1973, the President requested that each Department and Agency Head seek a sharper focus on the results that the various activities under his or her direction are aimed at achieving. In response, NSF identified two Presidential-level objectives during fiscal year 1974 as part of the Management by Objectives Program. These objectives were:

Objective I: Director's assumption of responsibilities as the President's Science Adviser, assigned by Reorganization Plan No. 1 of 1973, to provide policy and program guidance and assistance concerning the achievement of national goals through science and technology.

Objective II: Increase the contribution of science to society. The status of progress in attaining these objectives was reported regularly to the Executive Office of the President during the year. Substantial progress was made in both cases.

The fiscal year 1974 NSF Authorization Act required, for the first time, that a quarterly report on the status of funding and programs be provided to Congress. NSF prepared four such quarterly reports during fiscal year 1974 containing information on recent research results, changes in planned activity, and highlights of interesting program developments.

Evaluation Activities

Evaluation activities provide objective analyses of the effectiveness, impact, and adequacy of the Foundation's programs and plans. Such a study is the one undertaken of the NSF Institutional Science Development Program. While this extensive program has been completed, its achievements are being evaluated and its management philosophy is being studied as a model for future programs.

Under the International Biological Program, NSF supported studies in several distinct biomes (major habitat types). Three of these biome programs are being evaluated in regard to the scientific findings, the impact on scientists, and the management of the projects.

A computerized allocation and impact model was developed and is operational. This model allows direct assessment of the impacts of changes in NSF project budgets on faculty man-years, principal investigators supported, postdoctoral and other nonfaculty personnel supported, graduate students supported, and permanent equipment purchased, by discipline, by institution, or by State. The factors have now been extended to all other Federal agencies sponsoring academic research so that the impact of alternative budgetary decisions can be assessed.

The impact of research may be evaluated by the frequency with which resulting publications are cited by scientists. A study is attempting to establish the role and importance of highly cited papers in several disciplines, with the field of chemistry already completed. This study will establish the utility of citation frequency as an indicator of quality or importance of research results. Under an NSF grant, the University of Illinois is analyzing the quality of graduate education and research in science and engineering. The study will assess changes in the quality of the leading institutions, in the quality of their graduates, and how these graduates progress in the job market.

Appendix A

National Science Board, NSF Staff, Advisory Committees and Panels

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and Applied Mathematics
University of Maryland

Robert W. Ritchie
University of Washington

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Computer Engineering
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Jeffrey D. Ullman
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NATIONAL AND INTERNATIONAL PROGRAMS

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Woods Hole, Mass.

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Woods Hole Oceanographic Institution
Woods Hole, Mass.

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Department of Fisheries
Food and Agriculture Organization
Via delle Terme di Caracalla
Rome, Italy

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Director
Environmental Data Service, NOAA
Department of Commerce

Robert W. Stewart
Director, Pacific Region
Marine Sciences Directorate
Victoria, B.C., Canada

Robert B. Abel
Director
National Sea Grant Program, NOAA
U.S. Department of Commerce

Warren S. Wooster
Dean, Rosenstiel School of Marine
& Atmospheric Science
University of Miami

International Decade of Ocean Exploration

Proposal Review Panel

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Office of Naval Research
Branch Office - London
FPO N.Y.

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Marine Geology & Geophysics
Laboratory, NOAA
Miami, Fla.

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Scripps Institution
of Oceanography
University of California, San Diego

Peter Tatro, CDR, USN
Acoustic Environmental Support
Detachment
Office of Naval Research
Arlington, Va.

Mr. John I. Ewing
Lamont-Doherty Geological Observatory
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University of California, San Diego

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Institute of Marine Sciences
University of Alaska

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Economics Department
Santa Monica, Calif.

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President, First Chicago University
Finance Corporation
Chicago, Ill.

Nathaniel Karol
Vice President for Finance
and Management
Hebrew Union College

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Special Assistant to the
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University Research Board
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Murray Hill, N.J.

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Robert J. Wedgeworth
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American Library Association
Chicago, Ill.

Lee G. Burchinal
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Office of Science Information
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National Science Foundation

Martin M. Cummings
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National Library of Medicine
Bethesda, Md.

Dr. L. Quincy Mumford
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Washington, D.C.

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National Agricultural Library
U.S. Department of Agriculture
Beltsville, Md.

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University of Illinois

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Benjamin H. Read
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Rustum Roy
Professor of Engineering
Pennsylvania State University

Alberta Siegel
Department of Psychiatry
Stanford University

Laurence Tribe
Professor of Law
Harvard University

Harriet Zuckerman
Center for Advanced Study in
Behavioral Sciences
Stanford, Calif.

Appendix B

Organization Changes and Staff Appointments

ORGANIZATION CHANGES:

OFFICE OF THE DIRECTOR

The following staff changes occurred in the immediate office of the Director. Theodore D. Drury, Special Assistant to the Director, to Associate Director for Public Programs in the Office of Government and Public Programs. Philip M. Smith, formerly Acting and Deputy Head, Office of Polar Programs, to Special Assistant to the Director.

The following activities were organized, reporting to the Office of the Director:

Science and Technology Policy Office

The Science and Technology Policy Office in July 1973, in support of the Director's role as Science Adviser to the President and as Chairman of the Federal Council for Science and Technology. The Office is responsible for matters of national civilian science and technology policy, developing policy options for solution of national civilian problems, appraising effectiveness of Federal and national R&D efforts, interacting with the total science community in matters of science policy, and providing advice and assistance in furthering U.S. international science and technology objectives.

International Scientific and Technical Activities

The international scientific and technical activities performed by the Office of Science and Technology became the responsibility of the Director in July 1973.

NSF Office of Energy R&D Policy

The NSF Office of Energy R&D Policy in August 1973, responsible for providing an independent source of advice and analysis of energy R&D and other energy-related programs to the Director, in support of his role as Science Adviser to the President, for use by the Executive Office of the President.

National Science Foundation Energy Council

The National Science Foundation Energy Council in May 1974, to coordinate energy-related problems within NSF as they pertain to NSF programs and in regard to NSF energy activities carried on together with other government agencies.

Office of Planning and Resources Management

The Office of Planning and Resources Management in June 1974. The Office consists of the Office of Budget, Programming and Planning Analysis and the Program Review Office, transferred from the Assistant Director for Administration.

ASSISTANT DIRECTOR FOR RESEARCH

The Biological Research Resources Program was established in the Division of Biological and Medical Sciences in November 1973.

The Office of Computing Activities was reorganized in November 1973, and redesignated the Division of Computer Research, in February 1974.

The Office of Energy-Related Research was established in February 1974.

The International Magnetospheric Study Coordination Office was established in the Division of Environmental Sciences in June 1974.

ASSISTANT DIRECTOR FOR EDUCATION

In February 1974, the Special Analytical Section in the Division of Science Resources Studies was dissolved and its resources reallocated to the Manpower and R&D Economic Studies Section to allow for the assumption of additional responsibilities relating to energy.

The Ethical and Human Value Implications of Science and Technology Program was transferred from the Office of the Director to the Assistant Director for Education in May 1974.

ASSISTANT DIRECTOR FOR NATIONAL AND INTERNATIONAL PROGRAMS

The Office of Science Information Service was reorganized in November 1973.

The Office for Climate Dynamics was established in May 1974.

ASSISTANT DIRECTOR FOR RESEARCH APPLICATIONS

The Division of Advanced Energy Research and Technology was established in September 1973.

ASSISTANT DIRECTOR FOR ADMINISTRATIVE OPERATIONS

The Directorate for Administrative Operations was established, in June 1974, replacing the Directorate for Administration.

The Equal Employment Opportunity Office was established in February 1974.

The Personnel Office was reorganized in June 1974.

The Mail and Communication Unit of the Administrative Services Office, was transferred from the Supply, Space and Communication Section to the Central Processing Section in June 1974. The Supply, Space and Communication Section was redesignated the Supply and Space Management Section.

OTHER STAFF CHANGES:

In addition to those in the Office of the Director, the following staff changes were also announced during the year.

APPOINTMENTS

Paul F. Donovan, Director, NSF Office of Energy R&D Policy
Paul P. Craig, Deputy Director, NSF Office of Energy R&D Policy
Russell C. Drew, Head, Science and Technology Policy Office
Jack Kratchman, Deputy Director, Office of Government and Public Programs
Norman A. Wulf, Assistant to the General Counsel, Office of the General Counsel
Frederick H. Abernathy, Head, Office of Energy-Related General Research

M. Kent Wilson, Deputy Head, Office of Energy-Related General Research

Thomas P. Meloy, Director, Division of Engineering

Paul G. Shewmon, Director, Division of Materials Research

Lowell J. Paige, Assistant Director for Education

Charles E. Falk, Director, Division of Science Resource Studies

Kendall N. Moulton, Deputy Head, Office of Polar Programs

Joseph O. Fletcher, Head, Office for Climate Dynamics

Manfred J. Cziesla, Head, NSF Tokyo

Sidney G. Smith, Head, Science Liaison Office, Bucharest, Romania

Richard J. Green, Deputy Assistant Director for Management and Utilization

Ali B. Cambel, Deputy Assistant Director for Analysis and Planning

Donald A. Beattie, Director, Division of Advanced Energy Research and Technology

Frederick T. Sparrow, Deputy Director, Office of Systems Integration and Analysis

Charles R. Hauer, Director, Office of Public Technology Projects

Lewis G. Mayfield, Acting Director, Division of Advanced Technology Applications

Martin Lefcowitz, Assistant to the General Counsel, Office of the General Counsel

Robert D. Lauer, Deputy Director for Program Management, Division of Advanced Technology Applications

Robert Rabin, Deputy Director for Energy Effects on the Environment, Division of Environmental Systems and Resources

Kenneth E. Brunot, Deputy Director Geothermal Energy Projects

Lewis A. Gist, Director, Equal Employment Office

RESIGNATIONS

Holt Ashley, Director, Division of Advanced Technology Applications, left the Foundation and returned to Stanford University.

Elisha C. Freedman, Head, Public Sector Office, Office of Experimental R&D Incentives, left the Foundation to accept a position as City Manager of Rochester, New York.

RETIREMENTS

Thomas E. Jenkins, Assistant Director for Administration

Keith R. Kelson, Special Advisor to the Assistant Director for Education

TRANSFER

Ernest R. Sohns, Deputy Head, Office of International Programs, to the State Department

NOMINEES TO THE NATIONAL SCIENCE BOARD

Dr. Jewel P. Cobb, Dean, Connecticut College New London, Connecticut

Dr. Norman Hackerman, President, William Marsh Rice University, Houston, Texas

Dr. W. N. Hubbard, Jr., President, The Upjohn Company, Kalamazoo, Michigan

Dr. Saunders Mac Lane, Max Mason Distinguished Service Professor of Mathematics, University of Chicago, Chicago, Illinois

Dr. Grover E. Murray, President, Texas Tech University, Lubbox, Texas

Dr. Donald B. Rice, Jr., President, Rand Corporation, Santa Monica, California

Dr. L. Donald Shields, President, California State University at Fullerton, Fullerton, California

Dr. James H. Zumberge, Chancellor, University of Nebraska, Lincoln, Nebraska

Drs. Hackerman and Murray have just completed full terms on the Board.

Appendix C

Financial Report for Fiscal Year 1974

Salaries and Expenses Appropriation

Fund Availability		
Fiscal Year 1974 appropriation	$576,260,000	
Unobligated balance carried forward from fiscal year 1973	64,394,617	
Adjustments to prior year accounts	655,505	
Fiscal year 1974 availability		$641,310,122
Obligations		
Scientific research project support:		
Atmospheric Sciences	$ 12,236,370	
Earth sciences	11,013,410	
Oceanography	13,344,668	
Biochemistry and physiology	32,836,334	
Cellular biology	13,132,272	
Ecology and population biology	21,777,567	
Physics	36,729,130	
Chemistry	26,645,070	
Astronomy	9,300,782	
Mathematical sciences	14,500,490	
Social sciences	24,920,261	
Engineering	28,088,502	
Materials research	35,558,974	
Computer research	9,762,500	
Subtotal, scientific research project support		$289,646,330
National and special research programs:		
Global atmospheric research program	$ 3,859,650	
International decade of ocean exploration	13,789,356	
Ocean sediment coring program	11,077,557	
Arctic research program	3,866,986	
U.S. Antarctic research program	24,735,444	
Oceanographic facilities and support	18,232,383	
Solar eclipse support	43,500	
National R&D assessment program	1,945,712	
Experimental R&D incentives	10,552,068	
Science and technology policy research	1,014,359	
Energy R&D policy research	2,524,450	
Subtotal, national and special research programs		$91,641,465
National research centers:		
National Astronomy and Ionosphere Center	$3,200,000	
Kitt Peak National Observatory	7,800,000	
Cerro Tololo Inter-American Observatory	2,600,000	
National Radio Astronomy Observatory	12,100,000	
National Center for Atmospheric Research	17,500,000	
Subtotal, national research centers		$43,200,000
Science information activities		$8,077,358
International cooperative scientific activities		$6,274,234
Research applied to national needs:		
Energy	$28,110,966	
Environment	25,849,980	
Productivity	15,703,727	
Resources	1,613,400	
Exploratory research and problem assessment	3,801,092	
Subtotal, research applied to national needs		$75,079,165
Intergovernmental science and research utilization		$964,290
Institutional improvement for science		$9,992,863
Graduate student support		$12,998,699
Science education improvement		$67,710,609
Planning and policy studies		$2,556,650
Program development and management		$31,657,311
Subtotal		$639,998,974
Unobligated balance lapsing from 1974 appropriation		$655,643
Unobligated balance carried forward to fiscal year 1975		$655,505
Total		$641,310,122

Special Foriegn Currency Appropriation		
Fund Availability		
Fiscal year 1974 appropriation	$3,000,000	
Unobligated balance carried forward from fiscal year 1973	2,655,584	
Fiscal year 1974 availability		$5,655,584
Obligations		
Total obligations for fiscal year 1974		$5,650,672
Unobligated balance carried forward to fiscal year 1975		$4,912
Total		$5,655,584
Trust Fund		
Fund Availability		
Unobligated balance brought forward from fiscal year 1973	$6,785	
Receipts from non-Federal sources	1,309,704	
Fiscal year 1974 availability		$1,316,489
Obligations		
National and special research programs:		
Ocean sediment coring program	$250,000	
Graduate student support:		
NATO fellowship program	106,674	
Gifts and donations	4,143	
Subtotal		$360,817
Unobligated balance carried forward to fiscal year 1975		$955,672
Total		$1,316,489

Appendix D

Patents Resulting from Activities Supported by the National Science Foundation

During fiscal year 1974 the Foundation received 89 invention disclosures and made rights determinations in 59 inventions, some of which were submitted in previous fiscal years. The determinations included decisions to dedicate the inventions to the public through publication in 36 cases, to permit the inventing university or organization to retain principal commercial rights in 14 cases, and to transfer NSF's rights to other interested agencies in 7 cases. These agencies have either allowed the grantee to retain principal rights or have filed patent applications on behalf of the Government. The Foundation took title to 4 patent applications. In one case, a university retained principal rights to an invention pursuant to the provisions of an Institutional Patent Agreement.

During fiscal year 1974 the Foundation received licenses under 17 patent applications filed by grantees who had been allowed to retain principal rights in their inventions.

In addition, the Foundation was notified that four patents have issued during fiscal year 1974 on the following inventions in which the Foundation acquired rights as specified below.

TITLE

Patent No. 3,746,794 entitled "Modulator Demodulator Apparatus for Communication of Digital Data over Voice-Grade Telephone Lines" issued on July 17, 1973, in the names of Jack Stifle and Michael Johnson arising from research supported by a grant to the University of Illinois;

Patent No. 3,770,012 entitled "Random Access Selection Apparatus" issued on November 6, 1973, in the names of Donald L. Bitzer et al arising from research supported by a grant to the University of Illinois. This invention relates to an information retrieval control device for a computer-based education system.

LICENSE

Patent No. 3,748,755 entitled "Circuit Base Model" issued on July 19, 1973, in the names of Robert Karplus et al arising from research supported by a grant to the University of California. The invention relates to a model to teach children the principles of electricity, magnetism, and electrochemistry;

Patent No. 3,789,519 entitled "Rotoplane Platform Energy Source" issued on February 5, 1974, in the names of Marshall Montgomery et al arising from research supported by a grant to the University of California. The invention relates to educational equipment to demonstrate the principles of mechanical energy storage and conversion.

Appendix E

Publications of the National Science Foundation, Fiscal Year 1974

1 U.S.-Republic of China Cooperative Science Program (NSF 73-14)
2 *Mosaic*, Vol. 4, No. 3 (NSF 73-15)
3 Cooperative Science Programs in Latin America (NSF 73-16)
4 Scientists and Engineers in Economic Development Program (NSF 73-17)
5 Research Management Improvement Program Announcement (NSF 73-18)
6 Summary of Awards, 1973, Division of Environmental Systems and Resources (NSF 73-19)
7 Student-Originated Studies, 1972, Abstract Reports (NSF 73-20)
8 List of Published Studies Which Evaluate Research Progress and Opportunities By Major Fields (NSF 73-21)
9 Research on The Subsystems and Systems for The Application of Solar Energy to the Heating and Cooling of Buildings, Program Solicitation (NSF 73-22)
10 Engineering Research Initiation Grants, 1974 (NSF 73-23)
11 France-United States Exchange of Scientists Program Announcement (NSF 73-24)
12 International Decade of Ocean Exploration, Program Description Definition, Second Report (NSF 73-25)
13 National Science Foundation Grants Administration Manual (NSF 73-26)
14 Decision-Related Research in the Field of Local Government Management, Program Solicitation (NSF 73-27)
15 Municipal Systems, Operations and Services: Evaluating the Organization of Service Delivery in Metropolitan Areas, Program Solicitation (NSF 73-28)
16 Improving the Dissemination and Use of Scientific and Technical Information (NSF 73-29)
17 *Mosaic*, Vol. 4, No. 4 (NSF 73-30)
18 Summary of Awards, Fiscal Year 1973, Division of Social Systems andd Human Resources (NSF 73-31)
19 United States-India Exchange of Scientists (NSF 73-32)
20 Experimental R&D Incentives Program, Experiment Announcement, No. 55, Medical Instrumentation (NSF 73-34)
21 Division of Environmental Systems and Resources (NSF 73-36)
22 Research Applied To National Needs, Guidelines For Preparation of Unnsolicited Proposals (NSF 73-37)
23 Ocean Sediment Coring Program Information Brochure (NSF 73-38)
24 Intergovernmental Science and Research Utilization Reports to the National Science Foundation (NSF 73-39)
25 Science Resources Studies Highlights: "Selected Characteristics of Five Engineering and Scientific Occupational Groups, 1972" (NSF 73-306)
26 Science Resources Studies Highlights: "Federal Support to Universities and Colleges Rises to $4.1 Billion in FY 1972" (NSF 73-307)
27 Science Resources Studies Highlights: "Academic R&D Expenditures Reached $3.3 Billion in 1972" (NSF 73-308)
28 Federal Scientific, Technical, and Health Personnel, 1971 (NSF 73-309)
29 Science Resources Studies Highlights: "Graduate Science Enrollment Declines 2 Percent From 1971 to 1972" (NSF 73-310)
30 Science Resources Studies Highlights: "Immigrant Scientists and Engineers Decline in FY 1972, Physicians Increase Sharply" (NSF 73-311)
31 Science Resources Studies Highlights: "Federal R&D Funding Shows Little Change, Though Priorities Shift" (NSF 73-312)
32 Science Resources Studies Highlights: "Federal R&D Support to State and Local Governments Gains in Emphasis" (NSF 73-313)
33 Science Resources Studies Highlights: "Continued Growth Recorded for Federal Civilian R&D Programs" (NSF 73-314)
34 Graduate Science Education, Student Support and Postdoctorals, Fall 1972 (NSF 73-315)
35 An Analysis of Federal R&D Funding By Function, Fiscal Years 1969-74 (NSF 73-316)
36 Science Resources Studies Highlights: "Industrial Research and Development Approaches $20 Billion in 1972" (NSF 73-317)
37 Chemicals and Health, Report of the Panel on Chemicals and Health of the President's Science Advisory Committee, 1973 (NSF 73-500)
38 Twenty-Third Annual Report, 1973, National Science Foundation (NSF 74-1)
39 Grants and Awards, 1973, National Science Foundation (NSF 74-2)
40 National Science Foundation Databook (NSF 74-3)
41 Decision-Related Research on Technology Utilized By Local Governments, Program Solicitation (NSF 74-4)
42 *Mosaic*, Vol. 5, No. 1 (NSF 74-5)
43 United States-Japan Cooperative Science Program (NSF 74-6)
44 National Science Foundation Guide To Programs, Fiscal Year 1974(NSF 74-7)
45 Design Studies For Experimental Application of Two-Way Cable Communications to Urban Social Service Delivery and Administration, Program Solicitation (NSF 74-8)
46 Ocean Thermal Energy Conversion, Program Solicitation (NSF 74-9)
47 Summary of Awards, Fiscal Year 1973, Office of Computing Activities (NSF 74-10)
48 Research on Wind Energy Conversion Systems, Program Solicitation (NSF 74-11)
49 Scientists and Engineers in Economic Development Program (NSF 74-12)
50 Improved Management of Large-Scale Interdisciplinary Research Projects, Program Solicitation (NSF 74-13)
51 Improved Management of Large Research Laboratories and Large Specialized Research Facilities, Program Solicitation (NSF 74-14)
52 The Growth of Scientific and Technical Information, A Challenge (NSF 74-15)
53 Grants For Improving Doctoral Dissertation Research in the Social Sciences (NSF 74-16)
54 Office for Oceanographic Facilities and Support, Program Brochure (NSF 74-16)
55 Summary of Awards, Fiscal Year 1972, Office of Exploratory Research and Problem Assessment (NSF 74-19)
56 Energy, Environment, Productivity—Proceedings of RANN Symposium, November 1973 (NSF 74-19)
57 *Mosaic*, Vol. 5, No. 2 (NSF 74-20)

58 The Effects of International Technology Transfers on the U.S. Economy (NSF 74-21)
59 RANN Document Center Energy Research and Technology Interim Bibliography and Abstracts (NSF 74-22)
60 United States-Australia Cooperative Science Program Brochure (NSF 74-23)
61 Instructions for the Preparation of Proposals Requesting Support for Oceanographic Equipment (NSF 74-24)
62 Instructions for the Preparation of Proposals Requesting Support for Marine Technicians (NSF 74-25)
63 Federal Funds for Research, Development, and Other Scientific Activities, Fiscal Years 1972, 1973, and 1974, Volume XXII (NSF 74-300)
64 Science Resources Studies Highlights: "Federal Scientific and Technical Personnel Increase Slightly in 1972; Health Personnel Gain Sharply" (NSF 74-301)
65 Science Resources Studies Highlights: "Immigration of Scientists and Engineers Drops Sharply in 1973; Physician Inflow Still Near 1972 Peak" (NSF 74-302)
66 A Listing of Publications, Division of Science Resources Studies, March 1974 (NSF 74-303)
67 National Patterns of R&D Resources, 1953-74 (NSF 74-304)
68 Federal Support to Universities, Colleges, and Selected Nonprofit Institutions, Fiscal Year 1972 (NSF 74-305)
69 Science Resources Studies Highlights: "Academic R&D Expenditures Up 9 Percent" (NSF 74-306)
70 Science Resources Studies Highlights: "Federal Funding in Higher Education: Academic Science Shows Decline in Fiscal Year 1973" (NSF 74-307)

71 Initial Reports of the Deep Sea Drilling Project, Vol. 17 (NSFSP-17)

72 Initial Reports of the Deep Sea Drilling Project, Vol. 20 (NSFSP-20)

73 Initial Reports of the Deep Sea Drilling Project, Vol. 21 (NSFSP-21)

74 Initial Reports of the Deep Sea Drilling Project, Vol. 22 (NSFSP-22)

75 Initial Reports of the Deep Sea Drilling Project, Vol. 23 (NSFSP-23)

76 Initial Reports of the Deep Sea Drilling Project, Vol. 25 (NSFSP-25)

Appendix F

National Research Centers Contractors

Associated Universities, Inc. (AUI)
Gerald F. Tape, President

National Radio Astronomy Observatory
David S. Heeschen, Director

AUI Member Universities:
Columbia University
Cornell University
Harvard University
The Johns Hopkins University
Massachusetts Institute of Technology
University of Pennsylvania
Princeton University
University of Rochester
Yale University

Association of Universities for Research in Astronomy, Inc. (AURA)
Gilbert Lee, President

Cerro Tololo Inter-American Observatory
Victor M. Blanco, Director
Kitt Peak National Observatory
Leo Goldberg, Director

AURA Member Universities:
University of Arizona
California Institute of Technology
University of California
University of Chicago
Harvard University
Indiana University
University of Michigan
Ohio State University
Princeton University
University of Texas at Austin
University of Wisconsin
Yale University

Cornell University
W. Donald Cooke, Vice President for Research

National Astronomy and Ionosphere Center
Frank D. Drake, Director, Ithaca, N.Y.
Harold D. Craft, Director, Observatory Operations, Arecibo, Puerto Rico

University Corporation for Atmospheric Research (UCAR)
Francis P. Bretherton, President

National Center for Atmospheric Research
Francis P. Bretherton, Director

UCAR Member Universities:
University of Alaska
University of Arizona

California Institute of Technology
University of California
The Catholic University of America
University of Chicago
Colorado State University
University of Colorado
Cornell University
University of Denver
Drexel University
Florida State University
Harvard University
University of Hawaii
Iowa State University
The Johns Hopkins University
University of Illinois at Urbana—Champaign
University of Maryland
Massachusetts Institute of Technology
McGill University
University of Miami
University of Michigan
University of Minnesota
University of Missouri
University of Nevada
New Mexico Institute of Mining and Technology
New York University
State University of New York at Albany
Ohio State University
University of Oklahoma
Oregon State University
Pennsylvania State University
Purdue University
The Rice University
Saint Louis University
Stanford University
Texas A&M University
University of Texas
University of Toronto
Utah State University
University of Utah
University of Washington
University of Wisconsin
Woods Hole Oceanographic Institution

Appendix G

Criteria for the Selection of Research Projects

SUMMARY

The National Science Foundation administers several different programs of research support corresponding to several legislatively assigned objectives. To the maximum degree possible, these activities are designed to utilize and enhance existing scientific research potential and institutions. Purposeful adjustments are made when indicated.

In the selection of individual projects a number of widely understood and acknowledged criteria are considered. In different programs, the different criteria must be assigned different weights, according to the objectives being pursued. Also these criteria relate in different ways to the distinctive characteristics of different types of research-performing organizations.

INTRODUCTION

Policy Context

Public support of scientific research, specifically including *basic* research, is an accepted feature of United States public policy. Such support has two recognized major objectives:

- To foster and maintain basic research as an investment toward future opportunities, as insurance against unforeseeable future dangers, and as a vital element of culture;
- To bring about prompt, effective performance of applied research and problem-oriented basic research—insofar as specific needs for these can be foreseen—in the light of current understanding.

The National Science Foundation

It is not possible to make the distinction between basic and applied research a sharp one, and the Foundation is one of several Federal agencies that supports research of both kinds. The Foundation, however, is unique in its mission to foster basic research *per se* and in its responsibility for future scientific research capability. Thus the National Science Foundation Act of 1950, as amended, authorizes "programs to strengthen scientific research potential" as well as "scholarships and graduate fellowships." The Act authorizes support both of basic and of applied research and—in combination with Presidential directive—use of an unrestricted range of performers.

Agency Objectives and Methods

The Foundation thus has been charged with advancing several different but interrelated major objectives:

- Accomplishment of basic research;
- Accomplishment of applied research in selected areas;

- Long-term maintenance and strengthening of potential to accomplish both basic and applied research in the future.

This range of objectives has been reflected in the development of several different program formats for NSF support of research. But despite the approximate correspondence of programs to objectives, it remains true that research support actions are often taken with more than a single end in view. Thus the Foundation's method of pursuing any one objective may be modified or restricted by consideration of the others.

Functions Performed

Where research support is concerned, functions performed by the Foundation include:

— Allocation of resources to fields of science, to classes of scientific activity, or to areas of application;

— Selection of individual projects to be supported;

— Direct establishment or adjustment of institutional structures or capabilities.

CRITERIA

Allocation of resources to fields of science and to areas of application is not further discussed in this notice, but many of the criteria for individual project selection require only slight modification for use at the higher level of aggregation. Criteria for the creation or modification of institutional structures are dealt with in a separate section.

The following is an enumeration of criteria employed in the selection of research projects. To simplify later discussion, they are grouped in four categories.

Category A

Criteria relating to competent performance of research—the technical adequacy of the performer and of his institutional base:

1. The scientist's training, past performance record, and estimated potential for future accomplishment;
2. The scientist's demonstrated awareness of previous and alternative approaches to his problem;
3. Probable adequacy of available or obtainable instrumentation and technical support.

Category B

Criteria relating to the internal structure of science itself:

4. Probability that the research will lead to important discoveries or valid, significant conceptual generalizations within its field of science or (in the most favorable cases) extending to other fields as well;
5. Probability that the research will lead to significant improvements or innovations of investigative method—again with possible extension to other fields of science.

Category C

Criteria relating to utility or relevance:

6. Probability that the research can serve as the basis for new invention or improved technology;
7. Probable contribution of the research to technology assessment—i.e., to estimating and predicting the direct and indirect, intended and unintended effects of existing or proposed technologies.
8. Identification of an immediate programmatic context and user of the anticipated research results.

Category D

Criteria relating to future and long-term scientific potential of the United States:

9. Probable influence of the research upon the capabilities, interests, and careers of participating graduate students, postdoctoral associates, or other junior researchers;
10. Probability that the research will lead to radiation and diffusion, not only of technical results, but also of standards of workmanship and a tradition of excellence in the field;
11. Anticipated effect upon the institutional structure of U.S. science.

Because none of these considerations is susceptible to precise quantification, or even in most cases to unambiguous rank ordering, it would be more accurately descriptive to speak not of "criteria" but rather of "factors considered." Moreover, very different relative weights must be attached to the different factors in the case of different agency objectives or programs, as is explained in a later section.

Discussion

The first three criteria—those relating to competent execution—are given first consideration in every program. Every NSF-supported project is expected at the least to produce some valid new information or relationships. The best way to ensure this is to insist upon competent scientists and adequate facilities. All other considerations which follow, then, are predicated upon the assumption that these first three criteria are universally applied and that competent performance will be the normal expectation.

Criteria 4 and 5—those relating to the internal structure of science—summarize succinctly what the scientific community understands by the phrase "intrinsic scientific merit."

Criteria 6 and 7—those relating to utility or relevance—cannot be made entirely distinct from the preceding two, since that science judged best by internal standards has almost invariably turned out in the long run to be the most useful. Valid generalizations and powerful methods of observation and measurement usually lead to new invention, improved technology, and more confident assessment. Conversely, applied investigations designed to support invention, technology, and assessment tend to succeed in these purposes to the extent that they do uncover valid generalizations or improved methods. Thus differences between the two types of criteria are mainly ones of motivational specificity and time horizon. Research is properly termed "applied" when we visualize using the results in a very specific context—usually defined in terms of some already-formulated systems concept—or when we expect it will prove diagnostic of some already-recognized problem.

This specific relationship of applied research to a particular systems concept and plan of development is made still more explicit in criterion 8.

Criteria 9, 10, and 11—those relating to long-term scientific potential—address not so much the content of the research as the circumstances under which it is performed. They include, of course, the quality of training of scientists, but extend beyond this to the processes of scientific communication and publication, the evolution of traditional scientific disciplines, the spawning of new "interdisciplinary" disciplines, the manner in which scientific careers are developed, the organizational structures and settings in which all this goes on, and in general how the scientific tradition and the living corps of scientific capability of our Nation are maintained. While these criteria are seldom dominant in project selection or program development, they are always considered. The policy of the Foundation is not to undertake for short-term reasons any action which would seriously jeopardize the long-range science potential of the Nation.

APPLICATION TO SPECIFIC PROGRAMS

As has been described, the first three criteria are vigorously applied in all Foundation programs, and the last three also are always kept in view. More specialized emphases characterize individual programs, as follows:

Scientific Research Project Support

In this core program the emphasis is overwhelmingly upon the criteria of intrinsic scientific merit (4 and 5). Consideration is also given to the utility criteria (6 and 7)—not on a project-by-project basis but rather as considerations influencing the general level of effort to be applied to entire fields and subfields of science. Considerable direct weight is also given to criteria 9, 10, and 11 (those relating to future and long-term potential). Projects are selected and administered not only to preserve but to enhance the essential character of proven successful institutions. Thus, it is Foundation policy to encourage such institutional and organizational features as:

- Participation in research by graduate students;
- Open publication of research results in the standard literature;
- Widest possible access to unique facilities for interested and competent scientists;
- Emphasis upon originality, elegance, and economy of method in university research; and
- Maintenance of vigorous informal communication through symposia, workshops, scientific meetings, etc.

Energy-Related General Research is administered as a specialized augmentation of Scientific Research Project Support. Here the utility criteria (6 and 7) play a major role—being decisive in selection of scientific areas eligible for participation. Within the eligible areas, individual projects compete on the basis of scientific merit. Criteria 9, 10, and 11 here play a role which is less direct and more passive than for the core Scientific Research Project Support Program.

National and Special Research Programs—The relative weight of the different criteria for these programs is essentially the same as for the Scientific Research Project Support discussed above. But, because there are for the most part large-scale coordinated efforts, often including a logistic component and requiring special planning and management, somewhat greater consideration is required for organizational and institutional factors (criterion 11)—as is further discussed in a later section.

Research Applied to National Needs—Here, criteria of utility (6, 7, and 8) play a dominant role. Criteria of scientific merit and long-range future potential, of course, are also considered. The utility criteria 6, 7, and in most cases 8, are applied to individual grants on a project-by-project basis. To help potential investigators meet these criteria and to ensure programmatic coherence, the Research Applications Directorate issues from time to time divisional program brochures, guidelines for preparation of unsolicited proposals, program solicitations, and occasionally, requests for proposals. Applicants for support are encouraged and assisted to establish communications with potential users of their results at an early stage of negotiations.

Criteria for Actions Which Create or Modify Institutional and Organizational Structures

Actions of this type occur frequently in the support of National Research Centers and under the National and Special Research Programs. The applicable criteria reflect greater intervention and responsibility on the part of the Government and decisions at a higher level of aggregation. They include:

Criteria of Need

Evidence of a real scientific need and an opportunity to attack important problems in a way, or on a scale, not otherwise feasible or available.

Evidence that the program objectives can better be achieved through the organization of a new structure than through use of an existing one.

Criteria of Long-Range Potential

Formulation of a mission well enough and broadly enough defined to hold out prospects of high scientific productivity over an extended period.

Evidence that a significant number of first-class scientists (as judged by their peers) believe deeply in the proposed activity and are willing to commit their personal scientific careers to it.

Evidence that the new structure and its programs will strengthen rather than detract from related work performed in other settings.

RELATIONSHIP TO SOME CHARACTERISTICS OF RESEARCH-PERFORMING ORGANIZATIONS

NSF policy is to use and reinforce proven strengths of U.S. scientific institutions. These institutions include organizations of different types, such as:

- Universities and colleges;
- Industrial research laboratories and in-house laboratories of Federal agencies;

- National Centers and other federally funded research centers;
- Vendors of R&D services.

The Foundation seeks to avoid inadvertently changing the characteristics of proven organizations—either through individual actions, or as the cumulative result of many actions. Purposeful changes may occasionally be encouraged for specific reasons. Some relevant characteristics of the different types of organization include the following:

- Universities and colleges (academic institutions proper) have as their two principal missions teaching and the development and propagation of new knowledge and understanding. As applied to these organizations, therefore, criteria 9 and 10 may be regarded as criteria of "mission relevance."

- Academic organizations, traditionally, are deeply committed to considerations of intrinsic scientific merit (criteria 4 and 5) in developing and selecting their own research programs. This is largely a consequence of peer evaluation and peer pressure exerted upon the individual scientist.

- Organization along disciplinary lines is a prominent feature of academic research tradition. This is an indispensable virtue insofar as it guarantees comprehensive peer evaluation of scientific research *results*, but it presents some limitations for problem-oriented research. It should be borne in mind that new disciplines emerge from time to time and that the focus of established disciplines evolves continually.

- Academic environments also tend to place extreme value upon originality, methodological elegance, and upon the initiative and scientific judgment of the individual investigator. This characteristic again presents some limitations for problem-oriented research.

- Industrial research laboratories and Federal agencies' in-house laboratories generally have as their mission the generation of new knowledge and understanding in areas judged to be of immediate or potential concern and use in carrying out the commercial activities of the parent company or the mission of the agency.

- National Centers and federally funded research centers have as their mission the generation of new knowledge and understanding judged to be needed or desirable in the public interest. These organizations are generally established to provide specialized research environments not readily obtainable in organizations of the other types.

- Vendors of R&D services include many of the "not-for-profit" R&D organizations and also a number of—usually more specialized—R&D companies. These organizations, in addition to maintaining some level of independent research, are unique in the extent to which they undertake contract research on topics and problems designated by outside purchasers. Collectively they constitute a reservoir of general purpose research capability for hire.

Discussion

Different factors tend to determine the scope and complexion of the research programs in the different types of organizations. Thus universities tend to be complement limited. For them the primary management decision is how many professional staff (faculty) to employ and which particular ones. Subsequently, these individuals determine program content. Industrial and mission agency in-house laboratories are "mission determined." That is, activity is weighed and selected according to mission requirements. Finally, R&D vendors are, at least to some extent, capability and market limited. Foundation policy is to recognize and, generally, to avoid disturbing these characteristic differences.

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